

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 1454.1120
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		09/980489
INTERNATIONAL APPLICATION NO. PCT/DE00/01001	INTERNATIONAL FILING DATE 3 April 2000	PRIORITY DATE CLAIMED 2 June 1999
TITLE OF INVENTION METHOD AND ARRANGEMENT FOR DETERMINING A TOTAL ERROR DESCRIPTION OF AT LEAST ONE PART OF A COMPUTER PROGRAMME AND COMPUTER PROGRAMME PRODUCT AND COMPUTER-READABLE STORAGE MEDIUM		
APPLICANT(S) FOR DO/EO/US Peter LIGGESMEYER		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
<ol style="list-style-type: none">1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.2. <input checked="" type="checkbox"/> This is an express request to immediately begin national examination procedures (35 U.S.C. 371(f)).3. <input checked="" type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).4. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))<ol style="list-style-type: none">a. <input checked="" type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).b. <input type="checkbox"/> has been transmitted by the International Bureau.c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).5. <input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).6. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))<ol style="list-style-type: none">a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).b. <input type="checkbox"/> have been transmitted by the International Bureau.c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).7. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).8. <input checked="" type="checkbox"/> An oath or declaration of the inventor (35 U.S.C. 371(c)(4)).9. <input checked="" type="checkbox"/> A translation of the Annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).		
Items 10-15 below concern document(s) or information included:		
<ol style="list-style-type: none">10. <input checked="" type="checkbox"/> An Information Disclosure Statement Under 37 CFR 1.97 and 1.98.11. <input checked="" type="checkbox"/> An assignment document for recording. Please mail the recorded assignment document to:<ol style="list-style-type: none">a. <input checked="" type="checkbox"/> the person whose signature, name & address appears at the bottom of this document.b. <input type="checkbox"/> the following:12. <input checked="" type="checkbox"/> A preliminary amendment.13. <input checked="" type="checkbox"/> A substitute specification14. <input type="checkbox"/> A change of power of attorney and/or address letter.15. <input checked="" type="checkbox"/> Other items or information:		
PCT EASY forms filed with International Application; copies of cover page of International Application as published, International Search Report, and International Preliminary Examination Report; and two CD-R discs in IBM-PC format with MS-Windows operating system compatibility, each storing the file PROGRA~6.TXT (Program-Listing.txt in Windows) of 130,121 bytes, created November 29, 2001.		

☒ The U.S. National Fee (35 U.S.C. 371(c)(1)) and other fees as follows:

0.9 / 980489

CLAIMS	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
	TOTAL CLAIMS	15 -20=	0	x \$ 18.00	0.00
	INDEPENDENT CLAIMS	3 -3=	0	x \$ 84.00	0.00
	MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+\$280.00	0.00
	BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(4):				
	<input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO\$1,040 <input checked="" type="checkbox"/> International preliminary examination fee (37 C.F.R. 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO.....\$ 890 <input type="checkbox"/> International preliminary examination fee (37 C.F.R. 1.482) not paid to USPTO but international search fee (37 C.F.R. 1.445(a)(2)) paid to USPTO...\$ 740 <input type="checkbox"/> International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provision of PCT Article 33(1)-(4).....\$ 710 <input type="checkbox"/> International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2) to (4)\$ 100				890.00
	Surcharge of \$130 for furnishing the National fee or oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 mos. from the earliest claimed priority date (37 CFR 1.482(e)).				0.00
	TOTAL OF ABOVE CALCULATIONS				890.00
	Reduction by 1/2 for filing by small entity, if applicable. Affidavit must be filed also. (Note 37 CFR 1.9, 1.27, 1.28.)				
	SUBTOTAL				890.00
	Processing fee of \$130 for furnishing the English Translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 mos. from the earliest claimed priority date (37 CFR 1.482(f)).				
	TOTAL NATIONAL FEE				890.00
	Fee for recording the enclosed assignment (37 CFR 1.21(h)).				+ 40.00
	TOTAL FEES ENCLOSED				930.00

- a. ☒ A check in the amount of \$ 930.00 to cover the above fees is enclosed.
 b. ☐ Please charge my Deposit Account No. 19-3935 in the Amount of \$ to cover the above fees. A duplicate copy of this sheet is enclosed.
 c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 19-3935. A duplicate copy of this sheet is enclosed.



21171

PATENT TRADEMARK OFFICE

SUBMITTED BY: STAAS & HALSEY LLP

Type Name	Richard A. Gollhofer	Reg. No.	31,106
Signature	<i>Richard A. Gollhofer</i>	Date	12/3/01

Docket No.: (NEW) 1454.1120

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

Peter LIGGESMEYER

Serial No.

Group Art Unit: (NEW)

Confirmation No.

Filed: (concurrently)

Examiner:

For: SYSTEM FOR DETERMINING A TOTAL ERROR DESCRIPTION OF AT LEAST ONE
PART OF A COMPUTER PROGRAM (as amended)

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Before examination of the above-identified application, please amend the application as follows:

IN THE TITLE:

Please DELETE the Title in its entirety and REPLACE with the following new Title.

--SYSTEM FOR DETERMINING A TOTAL ERROR DESCRIPTION OF AT LEAST ONE
PART OF A COMPUTER PROGRAM--

IN THE ABSTRACT:

Please DELETE the Abstract in its entirety and substitute the attached new Abstract.

IN THE SPECIFICATION:

Please REPLACE the Specification in its entirety with the attached Substitute Specification wherein the program listing on pages 20-82 has been deleted and replaced by the program listing in the compact disc appendix submitted herewith.

IN THE CLAIMS:

Please CANCEL claims 1-16 without prejudice or disclaimer and ADD new claims 17-31 in accordance with the following:

17. (NEW) A method for using a computer to ascertain an overall fault description for at least one section of a computer program, comprising:

- storing a section of the computer program;
- ascertaining a control flow description for the section of the computer program, to describe a flow of control information in the section of the computer program;
- ascertaining a data flow description for the section of the computer program, to describe a flow of data in the section of the computer program;
- combining the control and data flow descriptions into a joint flow description for the section of the computer program;
- selecting program elements from the section of the computer program;
- storing a fault description for each reference element to describe possible faults in the reference element;
- ascertaining an element fault description for each selected program element, based on the fault description associated with a corresponding reference element, to describe possible faults in the selected program element; and
- ascertaining the overall fault description using the element fault descriptions, with a structure of the overall fault description taking into account a structure of the joint flow description.

18. (NEW) The method as claimed in claim 17, wherein the control flow description is a control flow graph.

19. (NEW) The method as claimed in claim 17, wherein the data flow description is a data flow graph.

20. (NEW) The method as claimed in claim 17,
- wherein the fault description is a stored fault tree,
 - wherein the element fault description is ascertained as an element fault tree, and
 - wherein the overall fault description is ascertained as an overall fault tree.

21. (NEW) The method as claimed in claim 17, further comprising performing fault analysis in the section of the computer program using the overall fault description.

22. (NEW) The method as claimed in claim 17,
wherein the overall fault description is ascertained as an overall fault tree, and
wherein said method further comprises altering the overall fault tree in terms of
prescribable boundary conditions.

23. (NEW) The method as claimed in claim 22, wherein said altering comprises adding
a complementary fault tree.

24. (NEW) A system for ascertaining an overall fault description for at least one section
of a computer program, comprising:

a storage unit to store the section of the computer program and fault descriptions
for reference elements, each fault description describing possible faults in one of the reference
elements; and

a processor, coupled to said storage unit,

to ascertain control and data flow descriptions for the section of the
computer program, the control flow description describing a flow of control information in the
section of the computer program and the data flow description describing a flow of data in the
section of the computer program,

to combine the control and data flow descriptions into a joint flow
description for the section of the computer program,

to select program elements from the section of the computer program,

to ascertain element fault descriptions for the program elements that have
been selected, to describe possible faults in each program element based on the fault description
associated with a corresponding reference element; and

to ascertain the overall fault description from the element fault
descriptions, with a structure of the overall fault description taking into account a structure of the
joint flow description.

25. (NEW) The system as claimed in claim 24, wherein said processor ascertains the
control flow description as a control flow graph.

26. (NEW) The system as claimed in claim 24, wherein said processor ascertains the
data flow description as a data flow graph.

27. (NEW) The system as claimed in claim 24,
wherein said storage unit stores each fault description as a fault tree, and
wherein said processor ascertains each element fault description as an element
fault tree and the overall fault description as an overall fault tree.

28. (NEW) The system as claimed in claim 24, wherein said processor further performs
fault analysis in the section of the computer program using the overall fault description.

29. (NEW) The system as claimed in claim 24, wherein said processor ascertains the
overall fault description as an overall fault tree and alters the overall fault tree in terms of
prescribable boundary conditions.

30. (NEW) The system as claimed in claim 29, wherein said processor alters the overall
fault tree by adding a complementary fault tree.

31. (NEW) A computer-readable storage medium storing at least one program to control
a computer to perform a method for ascertaining an overall fault description for at least one
section of a computer program, said method comprising:

storing a section of the computer program;
ascertaining a control flow description for the section of the computer program, to
describe a flow of control information in the section of the computer program;
ascertaining a data flow description for the section of the computer program, to
describe a flow of data in the section of the computer program;
combining the control and data flow descriptions into a joint flow description for
the section of the computer program;
selecting program elements from the section of the computer program;
storing a fault description for each reference element to describe possible faults
in the reference element;
ascertaining an element fault description for each selected program element,
based on the fault description associated with a corresponding reference element, to describe
possible faults in the selected program element; and
ascertaining the overall fault description using the element fault descriptions, with
a structure of the overall fault description taking into account a structure of the joint flow
description.

REMARKS

This Preliminary Amendment is submitted to improve the form of the English translation as filed. It is respectfully requested that this Preliminary Amendment be entered in the above-referenced application.

In accordance with the foregoing, claims 1-16 have been canceled and claims 17-31 have been added. Thus, claims 17-31 are pending and under consideration.

A substitute specification is also being filed herewith. The substitute specification is accompanied by a marked-up copy of the original specification.

If there are any additional fees associated with filing of this Preliminary Amendment, please charge the same to our Deposit Account No. 19-3935.

Respectfully submitted,

STAAS & HALSEY LLP

Date: 12/3/01

By: Richard A. Gollhofer
Richard A. Gollhofer
Registration No. 31,106

700 Eleventh Street, NW, Suite 500
Washington, D.C. 20001
(202) 434-1500

SUBSTITUTE SPECIFICATION

TITLE OF THE INVENTION

SYSTEM FOR DETERMINING A TOTAL ERROR

DESCRIPTION OF AT LEAST ONE PART OF A COMPUTER PROGRAM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and hereby claims priority to German Patent Application No. 19925239.4 filed on June 2, 2001, the contents of which are hereby incorporated by reference.

REFERENCE TO COMPUTER PROGRAM LISTING, COMPACT DISC APPENDIX

[0002] A compact disc is included herewith and incorporated by reference herein having thereon a computer program listing appendix in the ASCII uncompressed text format with ASCII carriage return, ASCII line feed and all control codes defined in ASCII, having computer compatibility with IBM PC/XT/AT or compatibles, having operating system compatibility with MS-Windows and including file PROGRA~6.TXT (Program-Listing.txt in Windows) of 130,121 bytes, created on November 29, 2001.

BACKGROUND OF THE INVENTION

[0003] The invention relates to a method and a system for ascertaining an overall fault description for at least one section of a computer program, and also to a computer product and a computer-readable storage medium.

[0004] Such a method and such a system are known from N. Leveson, "Safety Verification of ADA Programs Using Software Fault Trees", IEEE Software, July 1991, pages 48-59, which discloses the practice of using computers to ascertain an overall fault description in the form of an overall fault tree for a computer program. For the computer program, a control flow description is ascertained in the form of a control flow graph. For various program elements of the computer program, a stored fault description associated with a respective stored reference element is used to ascertain an element fault description. The fault description for a reference element describes possible faults in the respective reference element. The element fault descriptions in the form of element fault trees are used to ascertain the overall fault description, taking into account the control flow graph for the computer program.

[0005] The method and the system taught by Leveson have the following drawbacks, in particular. The overall fault tree ascertained is incomplete in terms of the faults examined and the causes thereof, and is therefore unreliable. Hence, this practice is not appropriate for use within the context of generating fault trees for a computer program for safety-critical applications. The individual fault trees associated with the reference elements are also incomplete and hence unreliable.

[0006] M. Weiser, "Program Slicing", in IEEE Transaction on Software Engineering, Vol. 10, No. 4, July 1984, pp. 352-357 provides an overview of "slicing". Slicing is the analysis carried out when searching for causes of incorrect action in a computer program. This procedure involves checking whether the incorrect action has been caused by an instruction currently under consideration. If this is not the case, the instructions which deliver data for or control the execution of the instruction are checked. This method is continued until no further operations exist, that is to say it gets to input data for the computer program. In slicing, "slices" are ascertained. A slice shows which instructions are affected in what way by a value under consideration. Below, the term slicing is always understood to mean backwardly directed slicing.

[0007] P. Liggesmeyer, Modultest und Modulverifikation – State of the Art, Mannheim, Vienna, Zurich: BI Wissenschaftsverlag, 1990 discloses the practice of ascertaining a control flow description and a data flow description for a computer program. In Liggesmeyer, this representation is used as an initial basis for "data-flow-oriented testing" of the computer program. The instructions (nodes) of the control flow graph are assigned data flow attributes (data flow description) which describe the nature of the data access operations contained in the instructions of the computer program. A distinction is drawn between write access operations and read access operations. Write access operations are referred to as definitions (def). Read access operations are referred to as a reference. If a read access operation takes place in a decision, this access operation is referred to as a predicative reference (p-use, predicate use). A read access operation during calculation of a value is referred to as a computational reference (c-use, computational use).

[0008] DIN 25424-1: Fehlerbaumanalysen; Methoden und Bildzeichen, September 1981, which has a title that can be translated "Fault Tree Analyses; Methods and Graphic Symbols", discloses principles relating to a fault tree. A fault tree is to be understood, as described in DIN 25424-1, to mean a structure which describes logical relationships between input variables for the fault tree which lead to a prescribed undesirable event.

[0009] In addition, DIN 25424-2: Fehlerbaumanalyse; Handrechenverfahren zur Auswertung eines Fehlerbaums, Berlin, Beuth Verlag GmbH, April 1990 which has a title that can be translated "Fault Tree Analysis; Manual Computation Methods for Evaluating a Fault Tree", discloses various methods for fault tree analysis.

SUMMARY OF THE INVENTION

[0010] The invention is based on the problem of ascertaining an overall fault description which is more reliable than ascertaining an overall fault tree in the manner known on the basis of the method taught by Leveson.

[0011] In a method for ascertaining an overall fault description for at least one section of a computer program, using a computer, at least the section of the computer program is stored. A control flow description and a data flow description are ascertained for the section of the computer program, and program elements are selected from the section of the computer program. For each selected program element, a stored fault description is used to ascertain an element fault description. The fault description is associated with a respective reference element. The element fault description describes possible faults in the respective program element. A fault description for a reference element describes possible faults in the respective reference element. The element fault descriptions are used to ascertain the overall fault description, which takes into account the control flow description and the data flow description.

[0012] A system for ascertaining an overall fault description for at least one section of a computer program has a processor which is set up such that the following method steps can be carried out:

- at least the section of the computer program is stored,
- a control flow description and a data flow description are ascertained for the section of the computer program,
- program elements are selected from the section of the computer program,
- for each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element,
- a fault description for a reference element describes possible faults in the respective reference element,

- the element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

[0013] A computer program product comprises a computer-readable storage medium on which a program is stored which, when it has been loaded into a memory in a computer, allows the computer to carry out the following steps for ascertaining an overall fault description for at least one section of a computer program:

- at least the section of the computer program is stored,
- a control flow description and a data flow description are ascertained for the section of the computer program,
- program elements are selected from the section of the computer program,
- for each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element,
- a fault description for a reference element describes possible faults in the respective reference element,
- the element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

[0014] A computer-readable storage medium stores a program which, when it has been loaded into a memory in a computer, allows the computer to carry out the following steps for ascertaining an overall fault description for at least one section of a computer program:

- at least the section of the computer program is stored,
- a control flow description and a data flow description are ascertained for the section of the computer program,
- program elements are selected from the section of the computer program,
- for each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element,
- a fault description for a reference element describes possible faults in the respective reference element,

- the element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

[0015] The invention now makes it possible to ascertain a reliable overall fault description, which takes into account the peculiarities of a computer program, for a computer program or a section thereof. Since the overall fault description ascertained is much more reliable than the overall fault description which can be ascertained on the basis of the method taught by Leveson, the invention is also suitable for safety-critical applications, i.e. in particular for ascertaining an overall fault description for a safety-critical computer program.

[0016] The control flow description and/or the data flow description may be in the form of a control flow graph or of a data flow graph, respectively.

[0017] The fault description may be in the form of a stored fault tree, and the element fault description can be ascertained as an element fault tree. In this case, the overall fault description can be ascertained as an overall fault tree. This development permits standardized representation of a fault description, which makes it much simpler for a user of the fault description to analyze same.

[0018] In one development, the overall fault description can be used for fault analysis in the section of the computer program. This development has the advantage, in particular, that automated, reliable fault analysis becomes possible, and if the fault descriptions are in the form of fault trees the fault description can even be analyzed in a manner "normalized" in accordance with the fault tree analysis methods.

[0019] In another refinement, the overall fault description is ascertained as an overall fault tree, and the overall fault tree is altered in terms of prescribable boundary conditions. The alteration can be made by adding a complementary fault tree.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] These and other objects and advantages of the present invention will become more apparent and more readily appreciated from the following description of the exemplary embodiment of the invention as explained in more detail below and as illustrated in the figures., in which:

[0021] Figure 1 is a block diagram of a computer used to carry out the method in accordance with the exemplary embodiment;

[0034] The memory 102 stores a computer program 104 for which an overall fault description is ascertained in the manner described below. In addition, the memory 102 stores a program 105 which implements the method described below. The memory also stores fault descriptions 115 for different reference elements of a computer program. A fault description for a reference element describes possible faults in the respective reference element. Various reference elements and fault descriptions associated with the reference elements are explained in detail below.

[0035] The input/output interface 106 has a keyboard 108 connected to it via a first connection 107. A second connection 109 is used to connect the input/output interface 106 to a computer mouse 110, and a third connection 111 is used to connect the input/output interface 106 to a screen 112 on which the overall fault description ascertained for the computer program 104 is displayed. A fourth connection 113 is used to connect the input/output interface 106 to an external storage medium 114.

[0036] Figure 2 shows a block diagram illustrating the procedure in accordance with the exemplary embodiment described below.

[0037] The stored computer program 104 is used to ascertain a control flow graph 201 and a data flow graph 202 for the computer program 104.

[0038] Individual program elements are selected from the computer program (step 203). For each program element selected, a stored fault description associated with a reference element corresponding to the selected program element is used to ascertain an element fault description (step 204). The element fault description describes possible faults in the respective selected program element.

[0039] On the basis of a fault event in the computer program (undesirable event), which fault event is prescribed by a user and needs to be examined, in a final step (step 205) an overall fault description for the computer program is ascertained, for the fault instance to be examined, from the element fault descriptions, taking into account the control flow graph and the data flow graph. The overall fault tree ascertained is displayed to the user on the screen 112.

[0040] Figure 3 shows the basic procedure for creating a fault tree, as used in the initial example in order to form the fault trees described below for the reference elements.

[0041] For an event 301 selected by a user, it is necessary to ascertain how the selected incorrect event can arise. In a computer program, incorrect output of a variable, as a selected

incorrect event (undesirable event) 301, can be caused by a control flow fault 303 and/or a data fault 304 (INCLUSIVE-OR function 302).

[0042] A control flow fault 303 is to be understood to mean incorrect control of the processing of the respective variable.

[0043] The data flow fault 304 is to be understood to mean a fault which arises during processing as a result of incorrect data. The data flow fault 304 may originate in the processing step currently under consideration (block 306) and/or it may already have been present and may be maintained only by fault propagation (block 307) (INCLUSIVE-OR function 305).

[0044] On the basis of these considerations, the appropriate fault tree, a slice describing the instruction and a control flow graph are respectively illustrated below for the following elements of a computer program:

- an instruction sequence,
- a selection element,
- a loop element.

Instruction sequence

[0045] The instruction sequence 401 comprises the three instructions shown in Fig. 4a. In a first instruction 402, a first variable j is assigned the value 3 ($j := 3$). A second instruction 403 assigns a second variable k the value 2 ($k := 2$). A third instruction 404 forms a sum using the first variable and the second variable ($i := j + k$).

[0046] In accordance with the practice disclosed in Weiser, a slice 410 is formed for this instruction sequence 401, as shown in Fig. 4b. The first instruction 402 and the second instruction 403 both affect the third instruction 404, which is illustrated by two arrows 411, 412 in the slice 410.

[0047] For the control flow graph 401, the fault tree 420 shown in Fig. 4c is obtained for the following prescribed undesirable event 421: "Variable i is incorrect after the third instruction".

[0048] The incorrect event 421 may have been produced by a fault in the third instruction 404 under consideration itself, if the data up to this instruction step were correct (element 422 in Fig. 4c). The incorrect event 421 may also be caused by corrupt input data for the third instruction, however, i.e. as a result of INCLUSIVE-ORing 424 the events that the second variable k was incorrect after the second instruction (element 425) and/or that the first variable j was incorrect after the first instruction 402 (element 426). The result of the first INCLUSIVE-ORed function

424 is INCLUSIVE-ORed with the event that the third instruction is incorrect (INCLUSIVE-OR function 423).

Selection element

[0049] With a selection element as reference element, it is necessary to consider possibilities of fault in the data flows and in the control flows within the computer program.

[0050] Figures 5a to 5c show a control flow graph 501 (cf. Fig. 5a), a slice 520 (cf. Fig. 5b) and a fault tree 540 (cf. Fig. 5c) for an If-Then-Else instruction as a selection element. The control flow graph 501 comprises the following six instructions:

- a first instruction 502, which assigns a first variable j the value 3 ($j := 3$),
- a second instruction 503, which assigns a second variable k a prescribable value ($k := \dots$),
- a third instruction 504, which checks whether the second variable k has a value greater than 0; if the value of the second variable is greater than 0, the instruction branches to a fourth instruction 505, otherwise it branches to a fifth instruction 506,
- the fourth instruction 505, which assigns a third variable i the value of the second variable k ($i := k$),
- a fifth instruction 506, which assigns the third variable i the value of the second variable k with a negative arithmetic sign ($i := -k$),
- a sixth instruction 507, which processes the third variable i further in an arbitrary manner.

[0051] For the control flow graph 501 shown in Fig. 5a, the slice 520 shown in Fig. 5b is obtained for the selection element. Solid edges in the slice 520 show a data dependency between the different instructions. Dashed edges indicate control dependencies between the appropriate instructions.

[0052] The following definitions apply for the two edge types:

- dashed edges, referred to as control edges below, are directed from instructions which contain a predicative reference (failure constructs, loop control) to the directly controlled instructions, i.e. to those instructions which are executed only if the predicate has a particular value. Control edges are drawn only between the controlling instruction and directly interleaved instructions. If a controlled block contains a further interleaved control level, no control edges crossing more than one level are drawn. Since a control relationship is transitive, this indirect control can be inferred from the slice by utilizing the transitivity.

- solid edges, referred to as data flow edges below, are directed from instructions in which a variable is defined to instructions in which this variable is referenced. The variable under consideration cannot be defined again between the definition and the reference. This is referred to as a definition-free path for the variable under consideration.

[0053] The slice is ascertained by searching the control flow graph, counter to the edge direction, for a definition of the variable under consideration starting from the instruction containing the variable under consideration, for which the undesirable event is prescribed. If computational references exist for the definition, the method is continued recursively until no further additional nodes are found. The dependencies found in this way between instructions are data dependencies. If a node under consideration is contained in a block whose execution is controlled directly by a decision, this represents a control dependency. For the predicative references of the variables involved in the decision, nodes with appropriate definitions - that is to say data flow dependencies - are recursively sought which have other control dependencies.

[0054] Figure 5b shows the failure element's associated slice 520 with corresponding control edges and data flow edges.

[0055] Figure 5c shows the fault tree 540 for the prescribed event "the third variable i is incorrect before the 6th instruction" 541.

[0056] The following events result in the incorrect event 541 when INCLUSIVE-ORed 542:

- ANDing 543 the events that the decision in accordance with the third instruction 504 is true (element 544) and a result of INCLUSIVE-ORing 545 the events that the fourth instruction 505 is incorrect (element 546) and/or the first variable j is incorrect after the first instruction 502 (element 547);
- ANDing 550 the events that the decision in accordance with the third instruction 504 is false (element 551) and a result of INCLUSIVE-ORing 552 the events that the fifth instruction is incorrect (element 553) and/or that the first variable j is incorrect after the first instruction 502 (element 554);
- INCLUSIVE-ORing 560 the following events: the decision in accordance with the third instruction 504 is incorrect (element 561) and/or the second variable k is incorrect after the second instruction 503 (element 562).

Multiple selection element

[0057] A multiple selection element as reference element can be handled in accordance with the scheme described above by breaking down the multiple selection into a cascade of two-way selection elements processed in accordance with the procedure above, in order thus to ascertain a fault tree for a multiple selection element.

Loop

[0058] Figures 6a to 6c show a fault tree 601 (cf. Fig. 6a), the corresponding slice 620 (cf. Fig. 6b) and the associated fault tree 640 (cf. Fig. 6c) for the reference element of a loop. The control flow graph 601 for a loop element comprises the following seven instructions:

- a first instruction 602, which assigns a first variable i the value 0 ($i := 0$),
- a second instruction 603, which assigns a second variable j an unspecified value ($j := \dots$),
- a third instruction 604, which prescribes a further unspecified value for a third variable k ($k := \dots$),
- a fourth instruction 605, which, as a loop instruction, specifies a condition that a fifth instruction and a sixth instruction are executed until the value of the second variable is $j > 0$ (WHILE $j > 0$ DO),
- a fifth instruction 606, which assigns the first variable i a value which is obtained from the sum of the previous value of the first variable and the product of the second variable and the third variable ($i := i + k * j$),
- a sixth instruction 607, which assigns the second variable j a value which is obtained by decreasing the original value of the second variable j by the value 1 ($j := j - 1$),
- a seventh instruction 608, which processes the first variable i further in a prescribable manner ($\dots := i \dots$).

[0059] Figure 6b shows the corresponding slice 620 for the control flow graph 601 shown in Fig. 6a with associated control flow edges and data flow edges. The fault tree 640 shown in Fig. 6c is formed for the prescribed event 641 that the "first variable i is incorrect before the seventh instruction".

[0060] The fault tree 640 is obtained by INCLUSIVE-ORing 642 the following four events:

- a first event 643, which describes a situation in which the first variable i is incorrect after the first instruction 602,

- ANDing 644 the events that the loop body has been passed through at least twice (element 645) and the event that the sixth instruction 607 is incorrect (646),
- ANDing 650 the event that the loop body has been executed at least once (element 651) and INCLUSIVE-ORing 652 of the following four events:
 - a) the fifth instruction 606 is incorrect (element 653),
 - b) the first variable i is incorrect after the first instruction (element 654),
 - c) the second variable j is incorrect after the second instruction (element 655),
 - d) the third variable k is incorrect after the third instruction (element 656),
- INCLUSIVE-ORing 660 the following three events:
 - e) the decision in accordance with the fourth instruction 605 is incorrect (element 661),
 - f) the second variable j is incorrect after the second instruction 603 (element 662),
 - g) ANDing 663 the events that the sixth instruction is incorrect (element 664) and the event that the loop body has been passed through at least once (element 665).

[0061] The fault trees described above, which are associated with the individual reference elements, are stored in the memory 102 as fault trees 115.

[0062] Figure 7 shows a control flow graph 700 for the following computer program:

```

input (n);
input (a);
max:=0;
sum:=0;
i:=2;
WHILE i =n DO
    IF max < a
    THEN max:= a
    sum:= sum + a
    i:= i + 1
avr:= sum/n;
output (max);
output (avr);

```


[illegible]

- [illegible]

[illegible][illegible][illegible][illegible]

- [illegible]

[illegible]

SUBSTITUTE ABSTRACT

SYSTEM FOR DETERMINING A TOTAL ERROR DESCRIPTION OF AT LEAST ONE PART OF A COMPUTER PROGRAM

A section of a computer program is used to ascertain a control flow description and a data flow description, and program elements are selected from the section of the computer program. For each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element. The element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

MARKED-UP SUBSTITUTE SPECIFICATION

[Description]

TITLE OF THE INVENTION

[METHOD AND ARRANGEMENT] SYSTEM FOR DETERMINING
A TOTAL ERROR DESCRIPTION OF AT LEAST ONE PART OF A
COMPUTER [PROGRAMME] PROGRAM [AND COMPUTER PROGRAMME
PRODUCT AND COMPUTER-READABLE STORAGE MEDIUM]

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and hereby claims priority to German Patent Application No. 19925239.4 filed on June 2, 2001, the contents of which are hereby incorporated by reference.

REFERENCE TO COMPUTER PROGRAM LISTING, COMPACT DISC APPENDIX

[0002] A compact disc is included herewith and incorporated by reference herein having thereon a computer program listing appendix in the ASCII uncompressed text format with ASCII carriage return, ASCII line feed and all control codes defined in ASCII, having computer compatibility with IBM PC/XT/AT or compatibles, having operating system compatibility with MS-Windows and including file PROGRA~6.TXT (Program-Listing.txt in Windows) of 130,121 bytes, created on November 29, 2001.

BACKGROUND OF THE INVENTION

[0003] The invention relates to a method and [an arrangement] a system for ascertaining an overall fault description for at least one section of a computer program, and also to a computer product and a computer-readable storage medium.

[0004] Such a method and such [an arrangement] a system are known from [1] [.] [1] N. Leveson, "Safety Verification of ADA Programs Using Software Fault Trees", IEEE Software, July 1991, pages 48-59, which discloses the practice of using computers to ascertain an overall fault description in the form of an overall fault tree for a computer program. For the computer program, a control flow description is ascertained in the form of a control flow graph. For various program elements of the computer program, a stored fault description associated with a respective stored reference element is used to ascertain an element fault description. The fault description for a reference element describes possible faults in the respective reference

element. The element fault descriptions in the form of element fault trees are used to ascertain the overall fault description, taking into account the control flow graph for the computer program.

[0005] The method and the [arrangement from] [1] system taught by Leveson have the following drawbacks, in particular. The overall fault tree ascertained is incomplete in terms of the faults examined and the causes thereof, and is therefore unreliable. Hence, this practice is not appropriate for use within the context of generating fault trees for a computer program for safety-critical applications. The individual fault trees associated with the reference elements are also incomplete and hence unreliable.

[0006] [2] M. Weiser, "Program Slicing", in: IEEE Transaction on Software Engineering, Vol. 10, No. 4, July 1984, pp. 352-357 provides an overview of "slicing". Slicing is the analysis carried out when searching for causes of incorrect action in a computer program. This procedure involves checking whether the incorrect action has been caused by an instruction currently under consideration. If this is not the case, the instructions which deliver data for or control the execution of the instruction are checked. This method is continued until no further operations exist, that is to say it gets to input data for the computer program. In slicing, "slices" are ascertained. A slice shows which instructions are affected in what way by a value under consideration. Below, the term slicing is always understood to mean backwardly directed slicing.

[0007] [3] P. Liggesmeyer, Modultest und Modulverifikation – State of the Art, Mannheim, Vienna, Zurich: BI Wissenschaftsverlag, 1990 discloses the practice of ascertaining a control flow description and a data flow description for a computer program. In [3] Liggesmeyer, this representation is used as an initial basis for "data-flow-oriented testing" of the computer program. The instructions (nodes) of the control flow graph are assigned data flow attributes (data flow description) which describe the nature of the data access operations contained in the instructions of the computer program. A distinction is drawn between write access operations and read access operations. Write access operations are referred to as definitions (def). Read access operations are referred to as a reference. If a read access operation takes place in a decision, this access operation is referred to as a predicative reference (p-use, predicate use). A read access operation during calculation of a value is referred to as a computational reference (c-use, computational use).

[0008] [4] DIN 25424-1: Fehlerbaumanalysen; Methoden und Bildzeichen, September 1981, which has a title that can be translated "Fault Tree Analyses; Methods and Graphic Symbols", discloses principles relating to a fault tree. A fault tree is to be understood, as described in [4]

DIN 25424-1, to mean a structure which describes logical relationships between input variables for the fault tree which lead to a prescribed undesirable event.

[0009] In addition, [5] DIN 25424-2: Fehlerbaumanalyse; Handrechenverfahren zur Auswertung eines Fehlerbaums, Berlin, Beuth Verlag GmbH, April 1990 which has a title that can be translated "Fault Tree Analysis; Manual Computation Methods for Evaluating a Fault Tree", discloses various methods for fault tree analysis.

SUMMARY OF THE INVENTION

[0010] The invention is based on the problem of ascertaining an overall fault description which is more reliable than ascertaining an overall fault tree in the manner known on the basis of the method [from] [1] taught by Leveson. [The problem is solved by the method and by the arrangement having the features in accordance with the independent claims and also by the computer product and the computer-readable storage medium having the features in accordance with the independent claims.]

[0011] In a method for ascertaining an overall fault description for at least one section of a computer program, using a computer, at least the section of the computer program is stored. A control flow description and a data flow description are ascertained for the section of the computer program, and program elements are selected from the section of the computer program. For each selected program element, a stored fault description is used to ascertain an element fault description. The fault description is associated with a respective reference element. The element fault description describes possible faults in the respective program element. A fault description for a reference element describes possible faults in the respective reference element. The element fault descriptions are used to ascertain the overall fault description, which takes into account the control flow description and the data flow description.

[0012] [An arrangement] A system for ascertaining an overall fault description for at least one section of a computer program has a processor which is set up such that the following method steps can be carried out:

- at least the section of the computer program is stored,
- a control flow description and a data flow description are ascertained for the section of the computer program,
- program elements are selected from the section of the computer program,

- for each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element,
- a fault description for a reference element describes possible faults in the respective reference element,
- the element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

[0013] A computer program product comprises a computer-readable storage medium on which a program is stored which, when it has been loaded into a memory in a computer, allows the computer to carry out the following steps for ascertaining an overall fault description for at least one section of a computer program:

- at least the section of the computer program is stored,
- a control flow description and a data flow description are ascertained for the section of the computer program,
- program elements are selected from the section of the computer program,
- for each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element,
- a fault description for a reference element describes possible faults in the respective reference element,
- the element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

[0014] A computer-readable storage medium stores a program which, when it has been loaded into a memory in a computer, allows the computer to carry out the following steps for ascertaining an overall fault description for at least one section of a computer program:

- at least the section of the computer program is stored,
- a control flow description and a data flow description are ascertained for the section of the computer program,
- program elements are selected from the section of the computer program,

- for each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element,
- a fault description for a reference element describes possible faults in the respective reference element,
- the element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

[0015] The invention now makes it possible to ascertain a reliable overall fault description, which takes into account the peculiarities of a computer program, for a computer program or a section thereof. Since the overall fault description ascertained is much more reliable than the overall fault description which can be ascertained on the basis of the method [from] [1] taught by Leveson, the invention is also suitable for safety-critical applications, i.e. in particular for ascertaining an overall fault description for a safety-critical computer program. [Preferred developments of the invention can be found in the dependent claims.]

[0016] The control flow description and/or the data flow description may be in the form of a control flow graph or of a data flow graph, respectively.

[0017] The fault description may be in the form of a stored fault tree, and the element fault description can be ascertained as an element fault tree. In this case, the overall fault description can be ascertained as an overall fault tree. This development permits standardized representation of a fault description, which makes it much simpler for a user of the fault description to analyze same.

[0018] In one development, the overall fault description can be used for fault analysis in the section of the computer program. This development has the advantage, in particular, that automated, reliable fault analysis becomes possible, and if the fault descriptions are in the form of fault trees the fault description can even be analyzed in a manner "normalized" in accordance with the fault tree analysis methods.

[0019] In another refinement, the overall fault description is ascertained as an overall fault tree, and the overall fault tree is altered in terms of prescribable boundary conditions. The alteration can be made by adding a complementary fault tree.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] [An] These and other objects and advantages of the present invention will become more apparent and more readily appreciated from the following description of the exemplary embodiment of the invention [is] as explained in more detail below and [is] as illustrated in the figures., in which:

[0021] Figure 1 [shows] is a block diagram of a computer used to carry out the method in accordance with the exemplary embodiment;

[0022] Figure 2 [shows] is a flowchart showing the individual method steps of the method in accordance with the exemplary embodiment;

[0023] Figure 3 [shows an illustration of] is a general fault tree, as formed basically for a reference element;

[0024] Figures 4a to 4c [show] are flow diagrams for a control flow graph ([figure] Fig. 4a), a slice ([figure] Fig. 4b) and a fault tree ([figure] Fig. 4c) for an instruction sequence as a reference element of a computer program;

[0025] Figures 5a to 5c [show] are flow diagrams for a control flow graph ([figure] Fig. 5a), a slice ([figure] Fig. 5b) and a fault tree ([figure] Fig. 5c) for a selection sequence as a reference element of a computer program;

[0026] Figures 6a to 6c [show] are flow diagrams for a control flow graph ([figure] Fig. 6a), a slice ([figure] Fig. 6b) and a fault tree ([figure] Fig. 6c) for a loop as a reference element of a computer program;

[0027] Figure 7 [shows] is a control flow graph with a data flow graph for a computer program in accordance with the exemplary embodiment;

[0028] Figures 8a and 8b [show] are flow diagrams for a slice for the output of the variable max ([figure] Fig. 8a) and a slice for the variable avr ([figure] Fig. 8b) for the program in accordance with the exemplary embodiment;

[0029] Figure 9 [shows] is a flow diagram for the slice for the variable avr, in which a structure of the loop from the program in accordance with the exemplary embodiment is highlighted;

[0030] Figure 10 [shows] is a flow diagram for a fault tree for the assumption that the variable avr is incorrect;

[0031] Figure 11 [shows] is a flow diagram for the overall fault tree based on [figure] Fig. 10, where redundant events from the overall fault tree based on [figure] Fig. 10 have been combined into one event.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0032] Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

[0033] Figure 1 shows a computer 100 used to carry out the method described below. The computer 100 has a processor 101 which is connected to a memory 102 via a bus 103. The bus 103 also has an input/output interface 106 connected to it.

[0034] The memory 102 stores a computer program 104 for which an overall fault description is ascertained in the manner described below. In addition, the memory 102 stores a program 105 which implements the method described below. The memory also stores fault descriptions 115 for different reference elements of a computer program. A fault description for a reference element describes possible faults in the respective reference element. Various reference elements and fault descriptions associated with the reference elements are explained in detail below.

[0035] The input/output interface 106 has a keyboard 108 connected to it via a first connection 107. A second connection 109 is used to connect the input/output interface 106 to a computer mouse 110, and a third connection 111 is used to connect the input/output interface 106 to a screen 112 on which the overall fault description ascertained for the computer program 104 is displayed. A fourth connection 113 is used to connect the input/output interface 106 to an external storage medium 114.

[0036] Figure 2 shows a block diagram illustrating the procedure in accordance with the exemplary embodiment described below.

[0037] The stored computer program 104 is used to ascertain a control flow graph 201 and a data flow graph 202 for the computer program 104.

[0038] Individual program elements are selected from the computer program (step 203). For each program element selected, a stored fault description associated with a reference element corresponding to the selected program element is used to ascertain an element fault description

(step 204). The element fault description describes possible faults in the respective selected program element.

[0039] On the basis of a fault event in the computer program (undesirable event), which fault event is prescribed by a user and needs to be examined, in a final step (step 205) an overall fault description for the computer program is ascertained, for the fault instance to be examined, from the element fault descriptions, taking into account the control flow graph and the data flow graph. The overall fault tree ascertained is displayed to the user on the screen 112.

[0040] Figure 3 shows the basic procedure for creating a fault tree, as used in the initial example in order to form the fault trees described below for the reference elements.

[0041] For an event 301 selected by a user, it is necessary to ascertain how the selected incorrect event can arise. In a computer program, incorrect output of a variable, as a selected incorrect event (undesirable event) 301, can be caused by a control flow fault 303 and/or a data fault 304 (INCLUSIVE-OR function 302).

[0042] A control flow fault 303 is to be understood to mean incorrect control of the processing of the respective variable.

[0043] The data flow fault 304 is to be understood to mean a fault which arises during processing as a result of incorrect data. The data flow fault 304 may originate in the processing step currently under consideration (block 306) and/or it may already have been present and may be maintained only by fault propagation (block 307) (INCLUSIVE-OR function 305).

[0044] On the basis of these considerations, the appropriate fault tree, a slice describing the instruction and a control flow graph are respectively illustrated below for the following elements of a computer program:

- an instruction sequence,
- a selection element,
- a loop element.

Instruction sequence

[0045] The instruction sequence 401 comprises the three instructions shown in [figure] Fig. 4a. In a first instruction 402, a first variable j is assigned the value 3 ($j := 3$). A second instruction 403 assigns a second variable k the value 2 ($k := 2$). A third instruction 404 forms a sum using the first variable and the second variable ($i := j + k$).

[0046] In accordance with the practice disclosed in [2] Weiser, a slice 410 is formed for this instruction sequence 401, as shown in [figure] Fig. 4b. The first instruction 402 and the second instruction 403 both affect the third instruction 404, which is illustrated by two arrows 411, 412 in the slice 410.

[0047] For the control flow graph 401, the fault tree 420 shown in [figure] Fig. 4c is obtained for the following prescribed undesirable event 421: "Variable i is incorrect after the third instruction".

[0048] The incorrect event 421 may have been produced by a fault in the third instruction 404 under consideration itself, if the data up to this instruction step were correct (element 422 in [figure] Fig. 4c). The incorrect event 421 may also be caused by corrupt input data for the third instruction, however, i.e. as a result of INCLUSIVE-ORing 424 the events that the second variable k was incorrect after the second instruction (element 425) and/or that the first variable j was incorrect after the first instruction 402 (element 426). The result of the first INCLUSIVE-ORed function 424 is INCLUSIVE-ORed with the event that the third instruction is incorrect (INCLUSIVE-OR function 423).

Selection element

[0049] With a selection element as reference element, it is necessary to consider possibilities of fault in the data flows and in the control flows within the computer program.

[0050] [Figure] Figures 5a to [figure] 5c show a control flow graph 501 (cf. [figure] Fig. 5a), a slice 520 (cf. [figure] Fig. 5b) and a fault tree 540 (cf. [figure] Fig. 5c) for an If-Then-Else instruction as a selection element. The control flow graph 501 comprises the following six instructions:

- a first instruction 502, which assigns a first variable j the value 3 ($j := 3$),
- a second instruction 503, which assigns a second variable k a prescribable value ($k := \dots$),
- a third instruction 504, which checks whether the second variable k has a value greater than 0; if the value of the second variable is greater than 0, the instruction branches to a fourth instruction 505, otherwise it branches to a fifth instruction 506,
- the fourth instruction 505, which assigns a third variable i the value of the second variable k ($i := k$),
- a fifth instruction 506, which assigns the third variable i the value of the second variable k with a negative arithmetic sign ($i := -k$),

- a sixth instruction 507, which processes the third variable *i* further in an arbitrary manner.

[0051] For the control flow graph 501 shown in [figure] Fig. 5a, the slice 520 shown in [figure] Fig. 5b is obtained for the selection element. Solid edges in the slice 520 show a data dependency between the different instructions. Dashed edges indicate control dependencies between the appropriate instructions.

[0052] The following definitions apply for the two edge types:

- dashed edges, referred to as control edges below, are directed from instructions which contain a predicative reference (failure constructs, loop control) to the directly controlled instructions, i.e. to those instructions which are executed only if the predicate has a particular value. Control edges are drawn only between the controlling instruction and directly interleaved instructions. If a controlled block contains a further interleaved control level, no control edges crossing more than one level are drawn. Since a control relationship is transitive, this indirect control can be inferred from the slice by utilizing the transitivity.
- solid edges, referred to as data flow edges below, are directed from instructions in which a variable is defined to instructions in which this variable is referenced. The variable under consideration cannot be defined again between the definition and the reference. This is referred to as a definition-free path for the variable under consideration.

[0053] The slice is ascertained by searching the control flow graph, counter to the edge direction, for a definition of the variable under consideration starting from the instruction containing the variable under consideration, for which the undesirable event is prescribed. If computational references exist for the definition, the method is continued recursively until no further additional nodes are found. The dependencies found in this way between instructions are data dependencies. If a node under consideration is contained in a block whose execution is controlled directly by a decision, this represents a control dependency. For the predicative references of the variables involved in the decision, nodes with appropriate definitions - that is to say data flow dependencies - are recursively sought which have other control dependencies.

[0054] Figure 5b shows the failure element's associated slice 520 with corresponding control edges and data flow edges.

[0055] Figure 5c shows the fault tree 540 for the prescribed event "the third variable *i* is incorrect before the 6th instruction" 541.

[0056] The following events result in the incorrect event 541 when INCLUSIVE-ORed 542:

- ANDing 543 the events that the decision in accordance with the third instruction 504 is true (element 544) and a result of INCLUSIVE-ORing 545 the events that the fourth instruction 505 is incorrect (element 546) and/or the first variable j is incorrect after the first instruction 502 (element 547);
- ANDing 550 the events that the decision in accordance with the third instruction 504 is false (element 551) and a result of INCLUSIVE-ORing 552 the events that the fifth instruction is incorrect (element 553) and/or that the first variable j is incorrect after the first instruction 502 (element 554);
- INCLUSIVE-ORing 560 the following events: the decision in accordance with the third instruction 504 is incorrect (element 561) and/or the second variable k is incorrect after the second instruction 503 (element 562).

Multiple selection element

[0057] A multiple selection element as reference element can be handled in accordance with the scheme described above by breaking down the multiple selection into a cascade of two-way selection elements processed in accordance with the procedure above, in order thus to ascertain a fault tree for a multiple selection element.

Loop

[0058] [Figure] Figures 6a to [figure] _6c show a fault tree 601 (cf. [figure] Fig. 6a), the corresponding slice 620 (cf. [figure] Fig. 6b) and the associated fault tree 640 (cf. [figure] Fig. 6c) for the reference element of a loop. The control flow graph 601 for a loop element comprises the following seven instructions:

- a first instruction 602, which assigns a first variable i the value 0 ($i := 0$),
- a second instruction 603, which assigns a second variable j an unspecified value ($j := \dots$),
- a third instruction 604, which prescribes a further unspecified value for a third variable k ($k := \dots$),
- a fourth instruction 605, which, as a loop instruction, specifies a condition that a fifth instruction and a sixth instruction are executed until the value of the second variable is $j > 0$ (WHILE $j > 0$ DO),
- a fifth instruction 606, which assigns the first variable i a value which is obtained from the sum of the previous value of the first variable and the product of the second variable and the third variable ($i := i + k * j$),

- a sixth instruction 607, which assigns the second variable j a value which is obtained by decreasing the original value of the second variable j by the value 1 ($j := j - 1$),
- a seventh instruction 608, which processes the first variable i further in a prescribable manner ($... := i ...$).

[0059] Figure 6b shows the corresponding slice 620 for the control flow graph 601 shown in [figure] Fig. 6a with associated control flow edges and data flow edges. The fault tree 640 shown in [figure] Fig. 6c is formed for the prescribed event 641 that the "first variable i is incorrect before the seventh instruction".

[0060] The fault tree 640 is obtained by INCLUSIVE-ORing 642 the following four events:

- a first event 643, which describes a situation in which the first variable i is incorrect after the first instruction 602,
- ANDing 644 the events that the loop body has been passed through at least twice (element 645) and the event that the sixth instruction 607 is incorrect (646),
- ANDing 650 the event that the loop body has been executed at least once (element 651) and INCLUSIVE-ORing 652 of the following four events:
 - a) the fifth instruction 606 is incorrect (element 653),
 - b) the first variable i is incorrect after the first instruction (element 654),
 - c) the second variable j is incorrect after the second instruction (element 655),
 - d) the third variable k is incorrect after the third instruction (element 656),
- INCLUSIVE-ORing 660 the following three events:
 - e) the decision in accordance with the fourth instruction 605 is incorrect (element 661),
 - f) the second variable j is incorrect after the second instruction 603 (element 662),
 - g) ANDing 663 the events that the sixth instruction is incorrect (element 664) and the event that the loop body has been passed through at least once (element 665).

[0061] The fault trees described above, which are associated with the individual reference elements, are stored in the memory 102 as fault trees 115.

[0062] Figure 7 shows a control flow graph 700 for the following computer program:

```
input (n);
input (a);
```

```

max:=0;
sum:=0;
i:=2;
WHILE i =n DO
    IF max < a[i]
    THEN max:= a[i]
    sum:= sum + a[i]
    i:= i + 1
avr:= sum/n;
output (max);
output (avr);

```

[0063] For the control flow graph 700 comprising 13 instructions (reference symbols 1, 2, 3, ..., 13) which is shown in [figure] Fig. 7, [figure] Fig. 8a shows the associated slice 800 for the variable max and [figure] Fig. 8b shows the associated slice 810 for the variable avr. The numbering of the individual instructions in the slices corresponds to the numbering of the individual instructions in the control flow graph 700 from [figure] Fig. 7.

[0064] Figure 9 shows the slice 900 for the variable avr, as shown in [figure] Fig. 8b. The structure of the loop element contained in the program shown above is highlighted in bold. This structure corresponds to the slice shown in [figure] Fig. 6b for a loop element.

[0065] An overall fault tree 1000 for the computer program shown above is shown in [figure] Fig. 10. The overall fault tree for the computer program is produced by instantiating the appropriate fault tree associated with the reference element which corresponds to the selected program element.

[0066] By starting from the prescribed undesirable event and working backward, the overall fault tree 1000 is thus ascertained using the fault trees associated with the reference elements.

[0067] Figure 10 contains the fault tree 1000 relating to the event that "the variable avr is incorrect before the thirteenth instruction" (element 1001). The variable avr may be incorrect before the thirteenth instruction 13 on account of at least one of the following three events, as is also shown in the slice 900 shown in [figure] Fig. 9 for the variable avr (INCLUSIVE-OR function 1002):

- an input variable n is incorrect after the first instruction 1 (element 1003),
- the eleventh instruction 11 is incorrect (element 1004),

- the value of the variable sum is incorrect before the eleventh instruction 11 (element 1005).

[0068] The variable sum is incorrect before the eleventh instruction 11 (element 1005) if at least one of the following events is satisfied (INCLUSIVE-OR function 1006):

- the variable sum is incorrect after the fourth instruction 4 (element 1007),
- ANDing 1008 the event that the loop body has been executed at least twice (element 1009) and the event that the tenth instruction 10 is incorrect (element 1010),
- ANDing 1011 the event that the loop body has been executed at least once (element 1012) and the result of INCLUSIVE-ORing 1013 the following four events:
 - a) the ninth instruction 9 is incorrect (element 1014),
 - b) the variable sum is incorrect after the fourth instruction 4 (element 1015),
 - c) the variable i is incorrect after the fifth instruction 5 (element 1016),
 - d) the variable a is incorrect after the second instruction 2 (element 1017),
- INCLUSIVE-ORing 1018 the following events:
 - e) the decision in accordance with the sixth instruction is incorrect (element 1019),
 - f) the variable i is incorrect after the fifth instruction (element 1020),
 - g) the variable n is incorrect after the first instruction (element 1021),
 - h) ANDing 1022 the event that the 10th instruction is incorrect (element 1023) and the event that the loop body has been executed at least once (element 1024).

[0069] To provide for clearer illustration, the fault tree 1000 from [figure] Fig. 10 is altered such that events shown a plurality of times in the fault tree 1000 are combined to form one node of a cause-effect graph 1100 (cf. [figure] Fig. 11).

[0070] The fault tree 1000 shown in [figure] Fig. 10 is subjected to a fault tree analysis method, as described in [5] DIN 25424-2, which analyzes an analysis of the computer program for a prescribed undesirable event.

[0071] The text below illustrates alternatives and further opportunities for application of the exemplary embodiment described above.

[0072] The overall fault tree produced using the method described above can be used for various purposes:

- description of the fault generation or propagation of incorrect action by a section of a computer program within the context of safety analysis or reliability analysis for the computer program,
- analysis of software fault mechanisms, for example within the context of test case generation.

[0073] The invention has been described in detail with particular reference to preferred embodiments thereof and examples, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

[The following publications are cited in this document:]

- [1] [N. Leveson, Safety Verification of ADA Programs using software fault trees, IEEE Software, pages 48 to 59, July 1991]
- [2] [Weiser M., *Program Slicing*, in: IEEE Transaction on Software Engineering, Vol. 10, No. 4, July 1984, pp. 352-357]
- [3] [Liggesmeyer P., *Modultest und Modulverifikation*] [Module Test and Module Verification] [- State of the Art, Mannheim, Vienna, Zurich: BI Wissenschaftsverlag 1990]
- [4] [DIN 25424-1: Fehlerbaumanalysen; Methoden und Bildzeichen] [Fault Tree Analyses; Methods and Graphic Symbols][, September 1981]
- [5] [DIN 25424-2: Fehlerbaumanalyse; Handrechenverfahren zur Auswertung eines Fehlerbaums] [Fault Tree Analysis; Manual Computation Methods for Evaluating a Fault Tree] [, Berlin, Beuth Verlag GmbH, April 1990]

GR 99 P 1974

12/pst

Description

Method and arrangement for ascertaining an overall fault description for at least one section of a computer program, and
5 computer program product and computer-readable storage medium

The invention relates to a method and an arrangement for ascertaining an overall fault description for at least one section of a computer program, and also to a computer product and a
10 computer-readable storage medium.

Such a method and such an arrangement are known from [1].

[1] discloses the practice of using computers to ascertain an
15 overall fault description in the form of an overall fault tree for a computer program. For the computer program, a control flow description is ascertained in the form of a control flow graph. For various program elements of the computer program, a stored fault description associated with a respective stored reference
20 element is used to ascertain an element fault description. The fault description for a reference element describes possible faults in the respective reference element. The element fault descriptions in the form of element fault trees are used to ascertain the overall fault description, taking into account the
25 control flow graph for the computer program.

The method and the arrangement from [1] have the following drawbacks, in particular. The overall fault tree ascertained is incomplete in terms of the faults examined and the causes thereof,
30 and is therefore unreliable. Hence, this practice is not appropriate for use within the context of generating fault trees for
a

computer program for safety-critical applications. The individual fault trees associated with

TEDEP 63408650

the reference elements are also incomplete and hence unreliable.

[2] provides an overview of "slicing". Slicing is the analysis carried out when searching for causes of incorrect action in a computer program. This procedure involves checking whether the incorrect action has been caused by an instruction currently under consideration. If this is not the case, the instructions which deliver data for or control the execution of the instruction are checked. This method is continued until no further operations exist, that is to say it gets to input data for the computer program. In slicing, "slices" are ascertained. A slice shows which instructions are affected in what way by a value under consideration. Below, the term slicing is always understood to mean backwardly directed slicing.

[3] discloses the practice of ascertaining a control flow description and a data flow description for a computer program. In [3], this representation is used as an initial basis for "data-flow-oriented testing" of the computer program. The instructions (nodes) of the control flow graph are assigned data flow attributes (data flow description) which describe the nature of the data access operations contained in the instructions of the computer program. A distinction is drawn between write access operations and read access operations. Write access operations are referred to as definitions (def). Read access operations are referred to as a reference. If a read access operation takes place in a decision, this access operation is referred to as a predicative reference (p-use, predicate use). A read access operation during calculation of a value is referred to as a computational reference (c-use, computational use).

[4] discloses principles relating to a fault tree. A

1990-1991		1991-1992		1992-1993		1993-1994		1994-1995		1995-1996		1996-1997		1997-1998		1998-1999		1999-2000		2000-2001		2001-2002		2002-2003		2003-2004		2004-2005		2005-2006		2006-2007		2007-2008		2008-2009		2009-2010		2010-2011		2011-2012		2012-2013		2013-2014		2014-2015		2015-2016		2016-2017		2017-2018		2018-2019		2019-2020		2020-2021		2021-2022		2022-2023		2023-2024		2024-2025		2025-2026		2026-2027		2027-2028		2028-2029		2029-2030		2030-2031		2031-2032		2032-2033		2033-2034		2034-2035		2035-2036		2036-2037		2037-2038		2038-2039		2039-2040		2040-2041		2041-2042		2042-2043		2043-2044		2044-2045		2045-2046		2046-2047		2047-2048		2048-2049		2049-2050		2050-2051		2051-2052		2052-2053		2053-2054		2054-2055		2055-2056		2056-2057		2057-2058		2058-2059		2059-2060		2060-2061		2061-2062		2062-2063		2063-2064		2064-2065		2065-2066		2066-2067		2067-2068		2068-2069		2069-2070		2070-2071		2071-2072		2072-2073		2073-2074		2074-2075		2075-2076		2076-2077		2077-2078		2078-2079		2079-2080		2080-2081		2081-2082		2082-2083		2083-2084		2084-2085		2085-2086		2086-2087		2087-2088		2088-2089		2089-2090		2090-2091		2091-2092		2092-2093		2093-2094		2094-2095		2095-2096		2096-2097		2097-2098		2098-2099		2099-2100		2100-2101		2101-2102		2102-2103		2103-2104		2104-2105		2105-2106		2106-2107		2107-2108		2108-2109		2109-2110		2110-2111		2111-2112		2112-2113		2113-2114		2114-2115		2115-2116		2116-2117		2117-2118		2118-2119		2119-2120		2120-2121		2121-2122		2122-2123		2123-2124		2124-2125		2125-2126		2126-2127		2127-2128		2128-2129		2129-2130		2130-2131		2131-2132		2132-2133		2133-2134		2134-2135		2135-2136		2136-2137		2137-2138		2138-2139		2139-2140		2140-2141		2141-2142		2142-2143		2143-2144		2144-2145		2145-2146		2146-2147		2147-2148		2148-2149		2149-2150		2150-2151		2151-2152		2152-2153		2153-2154		2154-2155		2155-2156		2156-2157		2157-2158		2158-2159		2159-2160		2160-2161		2161-2162		2162-2163		2163-2164		2164-2165		2165-2166		2166-2167		2167-2168		2168-2169		2169-2170		2170-2171		2171-2172		2172-2173		2173-2174		2174-2175		2175-2176		2176-2177		2177-2178		2178-2179		2179-2180		2180-2181		2181-2182		2182-2183		2183-2184		2184-2185		2185-2186		2186-2187		2187-2188		2188-2189		2189-2190		2190-2191		2191-2192		2192-2193		2193-2194		2194-2195		2195-2196		2196-2197		2197-2198		2198-2199		2199-2200		2200-2201		2201-2202		2202-2203		2203-2204		2204-2205		2205-2206		2206-2207		2207-2208		2208-2209		2209-2210		2210-2211		2211-2212		2212-2213		2213-2214		2214-2215		2215-2216		2216-2217	
-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--	-----------	--

which describes logical relationships between input variables for the fault tree which lead to a prescribed undesirable event.

In addition, [5] discloses various methods for fault tree
5 analysis.

The invention is based on the problem of ascertaining an overall fault description which is more reliable than ascertaining an overall fault tree in the manner known on the basis of the method
10 from [1].

The problem is solved by the method and by the arrangement having the features in accordance with the independent claims and also by the computer product and the computer-readable storage medium
15 having the features in accordance with the independent claims.

In a method for ascertaining an overall fault description for at least one section of a computer program, using a computer, at least the section of the computer program is stored. A control
20 flow description and a data flow description are ascertained for the section of the computer program, and program elements are selected from the section of the computer program. For each selected program element, a stored fault description is used to ascertain an element fault description. The fault description is
25 associated with a respective reference element. The element fault description describes possible faults in the respective program element. A fault description for a reference element describes possible faults in the respective reference element. The element fault descriptions are used to ascertain the overall fault
30 description, which takes into account the control flow description and the data flow description.

An arrangement for ascertaining an overall fault description for at least one section of a computer program has a processor which is set up such that the following method steps can be carried out:

- at least the section of the computer program is stored,
- 5 - a control flow description and a data flow description are ascertained for the section of the computer program,
- program elements are selected from the section of the computer program,
- for each selected program element, a stored fault description
10 associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element,
- a fault description for a reference element describes possible faults in the respective reference element,
- 15 - the element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

A computer program product comprises a computer-readable storage
20 medium on which a program is stored which, when it has been loaded into a memory in a computer, allows the computer to carry out the following steps for ascertaining an overall fault description for at least one section of a computer program:

- at least the section of the computer program is stored,
- 25 - a control flow description and a data flow description are ascertained for the section of the computer program,
- program elements are selected from the section of the computer program,
- for each selected program element, a stored fault

description which describes possible faults in the respective program element,

- a fault description for a reference element describes possible faults in the respective reference element,
- 5 - the element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

10 A computer-readable storage medium stores a program which, when it has been loaded into a memory in a computer, allows the computer to carry out the following steps for ascertaining an overall fault description for at least one section of a computer program:

- at least the section of the computer program is stored,
- a control flow description and a data flow description are
15 ascertained for the section of the computer program,
- program elements are selected from the section of the computer program,
- for each selected program element, a stored fault description associated with a respective reference element is used to
20 ascertain an element fault description which describes possible faults in the respective program element,
- a fault description for a reference element describes possible faults in the respective reference element,
- the element fault descriptions are used to ascertain the
25 overall fault description, taking into account the control flow description and the data flow description.

The invention now makes it possible to ascertain a reliable overall fault description, which takes into account the
30 peculiarities of a computer program, for a computer

program or a section thereof. Since the overall fault description
ascertained is much more reliable than the overall

FOUO "SECRET"

fault description which can be ascertained on the basis of the method from [1], the invention is also suitable for safety-critical applications, i.e. in particular for ascertaining an overall fault description for a safety-critical computer program.

5

Preferred developments of the invention can be found in the dependent claims.

10 The control flow description and/or the data flow description may be in the form of a control flow graph or of a data flow graph, respectively.

15 The fault description may be in the form of a stored fault tree, and the element fault description can be ascertained as an element fault tree. In this case, the overall fault description can be ascertained as an overall fault tree.

20 This development permits standardized representation of a fault description, which makes it much simpler for a user of the fault description to analyze same.

In one development, the overall fault description can be used for fault analysis in the section of the computer program.

25 This development has the advantage, in particular, that automated, reliable fault analysis becomes possible, and if the fault descriptions are in the form of fault trees the fault description can even be analyzed in a manner "normalized" in accordance with the fault tree analysis methods.

30

In another refinement, the overall fault description is ascertained as an overall fault tree, and the overall fault tree is altered in terms of prescribable boundary conditions.

The alteration can be made by adding a complementary fault tree.

An exemplary embodiment of the invention is explained in more detail below and is illustrated in the figures, in which:

5

Figure 1 shows a computer used to carry out the method in accordance with the exemplary embodiment;

Figure 2 shows a flowchart showing the individual method steps of the method in accordance with the exemplary embodiment;

10

Figure 3 shows an illustration of a general fault tree, as formed basically for a reference element;

Figures 4a to 4c show a control flow graph (figure 4a), a slice (figure 4b) and a fault tree (figure 4c) for an instruction sequence as a reference element of a computer program;

15

Figures 5a to 5c show a control flow graph (figure 5a), a slice (figure 5b) and a fault tree (figure 5c) for a selection sequence as a reference element of a computer program;

20

Figures 6a to 6c show a control flow graph (figure 6a), a slice (figure 6b) and a fault tree (figure 6c) for a loop as a reference element of a computer program;

Figure 7 shows a control flow graph with a data flow graph for a computer program in accordance with the exemplary embodiment;

25

Figures 8a and 8b show a slice for the output of the variable max (figure 8a) and a slice for the variable avr (figure 8b) for the program in accordance with the exemplary embodiment;

30

Figure 9 shows the slice for the variable avr, in which a structure of the loop from the program in accordance with the exemplary embodiment is highlighted;

Figure 10 shows a fault tree for the assumption that the variable avr is incorrect;

35

Figure 11 shows the overall fault tree based on figure 10, where redundant events from the overall fault tree based on figure 10 have been combined into one event.

Figure 1 shows a computer 100 used to carry out the method described below.

The computer 100 has a processor 101 which is connected to a
5 memory 102 via a bus 103. The bus 103 also has an input/output
interface 106 connected to it.

The memory 102 stores a computer program 104 for which an overall
fault description is ascertained in the manner described below. In
10 addition, the memory 102 stores a program 105 which implements the
method described below. The memory also stores fault descriptions
115 for different reference elements of a computer program. A
fault description for a reference element describes possible
15 faults in the respective reference element. Various reference
elements and fault descriptions associated with the reference
elements are explained in detail below.

The input/output interface 106 has a keyboard 108 connected to it
via a first connection 107. A second connection 109 is used to
20 connect the input/output interface 106 to a computer mouse 110,
and a third connection 111 is used to connect the input/output
interface 106 to a screen 112 on which the overall fault
description ascertained for the computer program 104 is displayed.
A fourth connection 113 is used to connect the input/output
25 interface 106 to an external storage medium 114.

Figure 2 shows a block diagram illustrating the procedure in accordance with the exemplary embodiment described below.

The stored computer program 104 is used to ascertain a control
5 flow graph 201 and a data flow graph 202 for the computer program
104.

Individual program elements are selected from the computer program
(step 203). For each program element selected, a stored fault
10 description associated with a reference element corresponding to
the selected program element is used to ascertain an element fault
description (step 204). The element fault description describes
possible faults in the respective selected program element.

15 On the basis of a fault event in the computer program (undesirable
event), which fault event is prescribed by a user and needs to be
examined, in a final step (step 205) an overall fault description
for the computer program is ascertained, for the fault instance to
be examined, from the element fault descriptions, taking into
20 account the control flow graph and the data flow graph.

The overall fault tree ascertained is displayed to the user on the
screen 112.

25 Figure 3 shows the basic procedure for creating a fault tree, as
used in the initial example in order to form the fault trees
described below for the reference elements.

For an event 301 selected by a user, it is necessary to ascertain
30 how the selected incorrect event can arise. In a computer program,
incorrect output of a variable, as a selected incorrect event

(undesirable event) 301, can be caused by a control flow fault 303 and/or a data fault 304 (INCLUSIVE-OR function 302).

A control flow fault 303 is to be understood to mean incorrect
5 control of the processing of the respective variable.

The data flow fault 304 is to be understood to mean a fault which arises during processing as a result of incorrect data.

10 The data flow fault 304 may originate in the processing step currently under consideration (block 306) and/or it may already have been present and may be maintained only by fault propagation (block 307) (INCLUSIVE-OR function 305).

15 On the basis of these considerations, the appropriate fault tree, a slice describing the instruction and a control flow graph are respectively illustrated below for the following elements of a computer program:

- an instruction sequence,
- 20 - a selection element,
- a loop element.

Instruction sequence

25 The instruction sequence 401 comprises the three instructions shown in figure 4a. In a first instruction 402, a first variable j is assigned the value 3 ($j := 3$). A second instruction 403 assigns a second variable k the value 2 ($k := 2$). A third instruction 404 forms a sum using the first variable and the second variable
30 ($i := j + k$).

In accordance with the practice disclosed in [2], a slice 410 is formed for this instruction sequence 401, as shown in figure 4b. The first instruction 402 and the second instruction 403 both affect the third instruction 404, which is illustrated by two
5 arrows 411, 412 in the slice 410.

For the control flow graph 401, the fault tree 420 shown in figure 4c is obtained for the following prescribed undesirable event 421:

10

"Variable i is incorrect after the third instruction".

The incorrect event 421 may have been produced by a fault in the third instruction 404 under consideration itself, if the data up
15 to this instruction step were correct (element 422 in figure 4c). The incorrect event 421 may also be caused by corrupt input data for the third instruction, however, i.e. as a result of INCLUSIVE-ORing 424 the events that the second variable k was incorrect after the second instruction (element 425) and/or that the first
20 variable j was incorrect after the first instruction 402 (element 426). The result of the first INCLUSIVE-ORed function 424 is INCLUSIVE-ORed with the event that the third instruction is incorrect (INCLUSIVE-OR function 423).

25 Selection element

With a selection element as reference element, it is necessary to consider possibilities of fault in the data flows and in the control flows within the computer program.

30

Figure 5a to figure 5c show a control flow graph 501 (cf. figure 5a), a slice 520 (cf. figure 5b) and a fault tree 540

(cf. figure 5c) for an If-Then-Else instruction as a selection element.

The control flow graph 501 comprises the following six instructions:

- a first instruction 502, which assigns a first variable j the value 3 ($j := 3$),
- a second instruction 503, which assigns a second variable k a prescribable value ($k := \dots$),
- 10 - a third instruction 504, which checks whether the second variable k has a value greater than 0; if the value of the second variable is greater than 0, the instruction branches to a fourth instruction 505, otherwise it branches to a fifth instruction 506,
- 15 - the fourth instruction 505, which assigns a third variable i the value of the second variable k ($i := k$),
- a fifth instruction 506, which assigns the third variable i the value of the second variable k with a negative arithmetic sign ($i := -k$),
- 20 - a sixth instruction 507, which processes the third variable i further in an arbitrary manner.

For the control flow graph 501 shown in figure 5a, the slice 520 shown in figure 5b is obtained for the selection element.

25

Solid edges in the slice 520 show a data dependency between the different instructions.

Dashed edges indicate control dependencies between the appropriate instructions.

30

The following definitions apply for the two edge types:

- dashed edges, referred to as control edges below, are directed from instructions which contain a predicative reference
- 35 (failure constructs, loop

control) to the directly controlled instructions, i.e. to those instructions which are executed only if

SECRET - 63403660

- the predicate has a particular value. Control edges are drawn only between the controlling instruction and directly interleaved instructions. If a controlled block contains a further interleaved control level, no control edges crossing more than one level are drawn. Since a control relationship is transitive, this indirect control can be inferred from the slice by utilizing the transitivity.
- solid edges, referred to as data flow edges below, are directed from instructions in which a variable is defined to instructions in which this variable is referenced. The variable under consideration cannot be defined again between the definition and the reference. This is referred to as a definition-free path for the variable under consideration.
- 15 The slice is ascertained by searching the control flow graph, counter to the edge direction, for a definition of the variable under consideration starting from the instruction containing the variable under consideration, for which the undesirable event is prescribed. If computational references exist for the definition, 20 the method is continued recursively until no further additional nodes are found. The dependencies found in this way between instructions are data dependencies. If a node under consideration is contained in a block whose execution is controlled directly by a decision, this represents a control dependency. For the 25 predicative references of the variables involved in the decision, nodes with appropriate definitions - that is to say data flow dependencies - are recursively sought which have other control dependencies.
- 30 Figure 5b shows the failure element's associated slice 520 with corresponding control edges and data flow edges.

Figure 5c shows the fault tree 540 for the prescribed event "the third variable i is incorrect before the 6th instruction" 541.

The following events result in the incorrect event 541 when

5 INCLUSIVE-ORed 542:

- ANDing 543 the events that the decision in accordance with the third instruction 504 is true (element 544) and a result of INCLUSIVE-ORing 545 the events that the fourth instruction 505 is incorrect (element 546) and/or the first variable j is
10 incorrect after the first instruction 502 (element 547);
- ANDing 550 the events that the decision in accordance with the third instruction 504 is false (element 551) and a result of INCLUSIVE-ORing 552 the events that the fifth instruction is incorrect (element 553) and/or that the first variable j is
15 incorrect after the first instruction 502 (element 554);
- INCLUSIVE-ORing 560 the following events: the decision in accordance with the third instruction 504 is incorrect (element 561) and/or the second variable k is incorrect after the second instruction 503 (element 562).

20

Multiple selection element

A multiple selection element as reference element can be handled in accordance with the scheme described above by breaking down the
25 multiple selection into a cascade of two-way selection elements processed in accordance with the procedure above, in order thus to ascertain a fault tree for a multiple selection element.

Loop

30

Figure 6a to figure 6c show a fault tree 601 (cf. figure 6a), the corresponding slice 620 (cf. figure 6b) and the associated fault tree 640 (cf. figure 6c) for the reference element of a loop.

- 5 The control flow graph 601 for a loop element comprises the following seven instructions:
- a first instruction 602, which assigns a first variable i the value 0 ($i := 0$),
 - a second instruction 603, which assigns a second variable j an
10 unspecified value ($j := \dots$),
 - a third instruction 604, which prescribes a further unspecified value for a third variable k ($k := \dots$),
 - a fourth instruction 605, which, as a loop instruction,
15 specifies a condition that a fifth instruction and a sixth instruction are executed until the value of the second variable is $j > 0$ (WHILE $j > 0$ DO),
 - a fifth instruction 606, which assigns the first variable i a value which is obtained from the sum of the previous value of the first variable and the product of the second variable and
20 the third variable ($i := i + k * j$),
 - a sixth instruction 607, which assigns the second variable j a value which is obtained by decreasing the original value of the second variable j by the value 1 ($j := j - 1$),
 - a seventh instruction 608, which processes the first variable i
25 further in a prescribable manner ($\dots := i \dots$).

Figure 6b shows the corresponding slice 620 for the control flow graph 601 shown in figure 6a with associated control flow edges and data flow edges.

30

The fault tree 640 shown in figure 6c is formed for the prescribed event 641 that the "first variable i is incorrect before the seventh instruction".

The fault tree 640 is obtained by INCLUSIVE-ORing 642 the following four events:

- a first event 643, which describes a situation in which the first variable i is incorrect after the first instruction 602,
- 5 - ANDing 644 the events that the loop body has been passed through at least twice (element 645) and the event that the sixth instruction 607 is incorrect (646),
- ANDing 650 the event that the loop body has been executed at least once (element 651) and INCLUSIVE-ORing 652 of the
- 10 following four events:
 - a) the fifth instruction 606 is incorrect (element 653),
 - b) the first variable i is incorrect after the first instruction (element 654),
 - c) the second variable j is incorrect after the second
 - 15 instruction (element 655),
 - d) the third variable k is incorrect after the third instruction (element 656),
- INCLUSIVE-ORing 660 the following three events:
 - e) the decision in accordance with the fourth instruction 605
 - 20 is incorrect (element 661),
 - f) the second variable j is incorrect after the second instruction 603 (element 662),
 - g) ANDing 663 the events that the sixth instruction is incorrect (element 664) and the event that the loop body
 - 25 has been passed through at least once (element 665).

The fault trees described above, which are associated with the individual reference elements, are stored in the memory 102 as fault trees 115.

Figure 7 shows a control flow graph 700 for the following computer program:

```
input (n);
5  input (a);
   max:=0;
   sum:=0;
   i:=2;
   WHILE i =n DO
10      IF max < a[i]
        THEN max:= a[i]
          sum:= sum + a[i]
          i:= i + 1
   avr:= sum/n;
15  output (max);
   output (avr);
```

For the control flow graph 700 comprising 13 instructions (reference symbols 1, 2, 3, ..., 13) which is shown in figure 7, figure 8a shows the associated slice 800 for the variable max and figure 8b shows the associated slice 810 for the variable avr. The numbering of the individual instructions in the slices corresponds to the numbering of the individual instructions in the control flow graph 700 from figure 7.

25

Figure 9 shows the slice 900 for the variable avr, as shown in figure 8b. The structure of the loop element contained in the program shown above is highlighted in bold. This structure corresponds to the slice shown in figure 6b for a loop element.

30

An overall fault tree 1000 for the computer program shown above is shown in figure 10. The overall fault tree for the computer program is produced by instantiating the appropriate fault tree associated with the reference element which corresponds to the selected program element.

35

By starting from the prescribed undesirable event and working backward, the overall fault tree 1000 is thus ascertained using the fault trees associated with the reference elements.

- 5 Figure 10 contains the fault tree 1000 relating to the event that
"the variable avr is incorrect before the thirteenth instruction"
(element 1001). The variable avr may be incorrect before the
thirteenth instruction 13 on account of at least one of the
following three events, as is also shown in the slice 900 shown in
10 figure 9 for the variable avr (INCLUSIVE-OR function 1002):
- an input variable n is incorrect after the first instruction 1
(element 1003),
 - the eleventh instruction 11 is incorrect (element 1004),
 - the value of the variable sum is incorrect before the eleventh
15 instruction 11 (element 1005).

The variable sum is incorrect before the eleventh instruction 11
(element 1005) if at least one of the following events is
satisfied (INCLUSIVE-OR function 1006):

- 20 - the variable sum is incorrect after the fourth instruction 4
(element 1007),
- ANDing 1008 the event that the loop body has been executed at
least twice (element 1009) and the event that the tenth
instruction 10 is incorrect (element 1010),
 - 25 - ANDing 1011 the event that the loop body has been executed at
least once (element 1012) and the result of INCLUSIVE-ORing
1013 the following four events:
 - a) the ninth instruction 9 is incorrect (element 1014),
 - b) the variable sum is incorrect after the fourth instruction
30 4 (element 1015),

- c) the variable i is incorrect after the fifth instruction 5
(element 1016),

SECRET 0000000000

- description of the fault generation or propagation of incorrect action by a section of a computer program within the context of safety analysis or reliability analysis for the computer program,
- analysis of software fault mechanisms, for example within the context of test case generation.

The text below shows a computer program in the programming language C++ which is used to implement the method in accordance with the exemplary embodiment:

```

5  #include "AS_GraphKante.h"

   #include <iostream>

10      ostream& operator << ( ostream& os, const GraphKanteC & Kante){

           os << Kante.KantenTyp;

15      return os;

           }

   //////////////////////////////////////
20  // Class for producing edges in the slice graph.
   // There are two types of edges:
   //      1. Control flow edges KFK
   //      2. Data flow edges DFK
   // This class also satisfies the nice-demands for the STL.
25  //
   //////////////////////////////////////
   // 1997-09-12 Andreas Steinhorst
   //////////////////////////////////////
   #ifndef _GraphNodeHeader
30  #define _GraphNodeHeader

   #include <iostream>
   #include "KFGListNode.h"

35  using namespace std;

   class GraphNodeC : public KFGListNodeC {
   public:

40      //GraphNodeC() {}

           friend ostream& operator << ( ostream& os, const GraphNodeC& Node);

           };

45  #endif

   //////////////////////////////////////
50  // Class for producing a slice. This class inherits an empty object from the
   // Graph class.
   // The corners of the graph/slice have the same structure as the lists in the CFG.
   // The edges are of type KantenTypT; a GraphKanteC class could not be incorporated
   // into the Graph class, for reasons which were not apparent to me.
55  //////////////////////////////////////
   // 1997-09-12 Andreas Steinhorst
   //////////////////////////////////////
   #ifdef _SliceHeader
   #else
60  #define _SliceHeader

   #include "graph.h"
   #include "AS_GraphKante.h"
   // #include "AS_GraphNode.h"
65  #include "KFGListNode.h"
   #include "KFGList.h"

           //using namespace std;
           //typedef enum {DFK, KFK} KantenTypT;
70

```

```

class SliceC : public Graph<KFGListNodeC,GraphKanteC> {
public:
5      SliceC() {};
      void sliceForLoops(KFGListC & L2, KFGListC::iterator LOOPIT);
      KFGListC::iterator defineVariableToSlice(KFGListC & L2);
10     //void buildTestGraph(KFGListC & L2);
      void findAllDefs(KFGListC & L1, KFGListC::iterator ITER);
15     KFGListC::iterator findUpperLimit(KFGListC & L1, KFGListC::iterator ITER,
      KFGP_UseListC::iterator PUSEIT);
      KFGListC::iterator findLowerLimit(KFGListC & L1, KFGListC::iterator ITER,
      KFGListC::iterator UPPERLIMIT);
20     KFGListC::iterator findLowerLimitFromCUse(KFGListC & L1, KFGListC::iterator
      ITER, KFGListC::iterator UPPERLIMIT);
      KFGListC::iterator findUpperLimitFromCUse(KFGListC & L1, KFGListC::iterator
25     ITER, KFGUseListC::iterator USEIT);
      int checkForNodes(int NodeNumber);
      void KFKPUseToCUse(KFGListC::iterator PUSEIT, int SchleifenEnde);
30     void findDefToCUse(KFGListC & L1, KFGListC::iterator ITER);
      void defInLoop(KFGListC & L1, KFGListC::iterator ITER);
35     void startBuildSlice(KFGListC & L1);
      void sliceAusgeben();
40     };
    #endif

    //////////////////////////////////////
45    // Taken with a few alterations from "The C++ Standard Template Library".
    //
    // Template Class Graph for producing directional or nondirectional graphs.
    // The graph comprises a vector E for all corners. Each vector element comprises,
    // in turn, a pair: the corner and the set of successors.
50    // The set of successors is represented by the STL data type map; the key for an
    // edge type/edge value is the number of a subsequent corner.
    //
    //////////////////////////////////////
55    #ifndef _graphHeader
    #define _graphHeader
    #include <assert.h>
    #include <map>
    #include <stack>
    #include <vector>
60    #include "checkvec.h"
    #include <iostream>
    #include "AS_GraphNode.h"
    using namespace std;

65    // Empty parameter class with minimum set of operations,
    // if no edge weights are required.
    struct Empty
    {
    public:
70        Empty(int=0) {}
        bool operator<(const Empty&) const { return true;}
    };
    // Empty operations so that in/output can be formulated in general terms
    // ostream& operator<<(ostream& os, const Empty&) { return os;}
75

```

```

//istream& operator>>(istream& is, Empty& ) { return is;}

template<class Eckentyp, class Kantentyp>
5 class Graph
{
    public:
        typedef map<int,Kantentyp, less<int> > Nachfolger;
        typedef pair<Eckentyp, Nachfolger> Ecke;
10        typedef checkedVector<Ecke> Graphtyp;
            //typedef vector<Ecke> Graphtyp;
        typedef Graphtyp::iterator iterator;
        typedef Graphtyp::const_iterator const_iterator;

15        Graph(bool g, ostream& os = cerr)
            : gerichtet(g), pOut(&os) {}

            Graph() {}

20        size_t size() const { return C.size(); }
        bool istGerichtet() const { return gerichtet;}
        iterator begin() { return C.begin();}
        iterator end() { return C.end();}
        Ecke& operator[] (int i) { return C[i];}

25        size_t AnzahlKanten();
        int insert(const Eckentyp& e);
        void insert(const Eckentyp& e1, const Eckentyp& e2,
            const Kantentyp& Wert);
30        void verbindeEcken(int e1, int e2, // using corner numbers
            const Kantentyp& Wert);
        void setgerichtet (bool wert); // new method for
directional/nondirectional graphs,
// although it
35 is not used.
        void check(ostream& = cout);
        void ZyklusUndZusammenhang(ostream& = cout);

        private:
40        bool gerichtet;
        Graphtyp C; // Container
        ostream* pOut;
    };

45 //Function which checks whether a directional or nondirectional graph is involved,
//and outputs the number of corners and edges.
template<class Eckentyp, class Kantentyp>
void Graph<Eckentyp,Kantentyp>::check(ostream& os)
{
50    os << "The graph is ";
    //if(!istGerichtet())
    //    os << "non";
    os << "directional and has "
        << size() << " nodes and "
55    << AnzahlKanten() << " edges\n";
    //ZyklusUndZusammenhang(os);
}

//Method which sets a value determining whether the graph is directional or
nondirectional.
60 template<class Eckentyp, class Kantentyp>
void Graph<Eckentyp,Kantentyp>::setgerichtet(bool wert)
{
    gerichtet = wert;
65 }

//Function calculates the number of edges in graph
template<class Eckentyp, class Kantentyp>
size_t Graph<Eckentyp,Kantentyp>::AnzahlKanten()
70 {
    size_t Kanten = 0;
    iterator temp = begin();
    while(temp != end())
        Kanten += (*temp++).second.size();
75 //if(!gerichtet)
    //    Kanten /= 2;

```

```

    return Kanten;
}

//Insert a corner into the graph if it does not yet exist.
5  template<class Eckentyp, class Kantentyp>
   int Graph<Eckentyp, Kantentyp>::insert(const Eckentyp& e)
   {
       for(int i = 0; i < size(); ++i)
           if(e == C[i].first)
10          return i;

       // if not found, insert:
       C.push_back(Ecke(e, Nachfolger()));
       return size()-1;
15  }

//Insert an edge into the graph by first inserting the corners.
template<class Eckentyp, class Kantentyp>
20  void Graph<Eckentyp, Kantentyp>::insert(const Eckentyp& e1,
                                           const Eckentyp& e2,
                                           const Kantentyp& Wert)
   {
       int pos1 = insert(e1);
       int pos2 = insert(e2);
25      verbindeEcken(pos1, pos2, Wert);
   }

//Connect the two newly inserted corners by means of an edge.
template<class Eckentyp, class Kantentyp>
30  void Graph<Eckentyp, Kantentyp>::verbindeEcken(
       int pos1, int pos2, const Kantentyp& Wert)
   {
       C[pos1].second[pos2] = Wert;
       //if(!gerichtet) // automatically enter opposite direction as well
       //  C[pos2].second[pos1] = Wert;
35  }

/* ZyklusUndZusammenhang() uses the depth search.
   In contrast to CLR S. 478, recursion has not been used, because it involved the
   occurrence of stack overflow with large graphs (e.g. MILES.DAT
   at more than 40 nodes). Simulating recursion using a separate stack makes it
   possible to process the whole MILES.DAT file (128 nodes). The stack depth
45  corresponds to the number of edges + 1 in the case of nondirectional
   graphs.
*/

template<class Eckentyp, class Kantentyp>
50  void Graph<Eckentyp, Kantentyp>::ZyklusUndZusammenhang(ostream& os)
   {
       int Zyklen = 0;
       int Komponentenzahl = 0;
       stack<int, vector<int>> > EckenStack; // corners to be visited
55
       // assign all corners the state nichtBesucht
       enum EckStatus {nichtBesucht, besucht, bearbeitet};
       vector<EckStatus> Eckenzustand(size(), nichtBesucht);

       // visit all corners
       for(int i = 0; i < size(); ++i)
           if(Eckenzustand[i] == nichtBesucht)
           {
               Komponentenzahl++;
65               // deposit on the stack for the purposes of processing
               EckenStack.push(i);

               // Process stack
               while(!EckenStack.empty())
70               {
                   int dieEcke = EckenStack.top();
                   EckenStack.pop();
                   if(Eckenzustand[dieEcke] == besucht)
                       Eckenzustand[dieEcke] = bearbeitet;
75               else

```

```

        if(Eckenzustand[dieEcke] == nichtBesucht)
        {
            Eckenzustand[dieEcke] = besucht;
            // make a note of new corner, for bearbeitet identifier
            EckenStack.push(dieEcke);

            // make a note of successor:
            Graph<Eckentyp, Kantentyp>::Nachfolger::iterator
            start = operator[] (dieEcke).second.begin(),
            ende = operator[] (dieEcke).second.end();
            while(start != ende)
            {
                int Nachf = (*start).first;
                if(Eckenzustand[Nachf] == besucht)
                {
                    ++Zyklen; // somebody has already been here!
                    (*pOut) << "at least corner "
                    << operator[] (Nachf).first
                    << " is in a cycle\n";
                }
                if(Eckenzustand[Nachf] == nichtBesucht)
                    EckenStack.push(Nachf);
                ++start;
            }
        } // Stack Empty?
    } // for() ... if(Eckenzustand...

    if(gerichtet)
    { if(Komponentenanzahl == 1)
        os << "The graph is very cohesive.\n";
        else
        os << "The graph is not or not very "
        "cohesive.\n";
    }
    else
        os << "The graph has "
        << Komponentenanzahl
        << " component(s)." << endl;

    os << "The graph has ";
    if(Zyklen == 0)
        os << "no ";
    os << "cycles." << endl;
}

//Output of the graph.
template<class Eckentyp, class Kantentyp>
ostream& operator<<(ostream& os,
                    Graph<Eckentyp, Kantentyp>& G)
{
    ofstream Ziel("FaultTree.uwg");
    ostream_iterator<uwgknotenC> POSIT(Ziel);
    ostream_iterator<uwgknotenC> POSIT2(Ziel);
    // Display the corners with successors
    Ziel << "%UWG" << endl << "%V0.1" << "fault tree" << "A.Steinhorst" <<
    endl << "%BEGIN" << endl;
    for(int i = 0; i < G.size(); ++i)
    {
        POSIT++ = G[i].first;
        /*os << G[i].first << " <";
        Graph<Eckentyp, Kantentyp>::Nachfolger::iterator
        startN = G[i].second.begin(),
        endeN = G[i].second.end();
        while(startN != endeN)
        {
            os << G[(*startN).first].first << ' ' // Ecke
            << (*startN).second << ' '; // Kantenwert
            *POSIT2++ = G[(*startN).first].first;
            //KANTEIT++ = (*startN).second;
            ++startN;
        }
        os << ">\n";*/
        *POSIT++;
    }
    for(int u = 0; u < G.size(); ++u) {
        Graph<Eckentyp, Kantentyp>::Nachfolger::iterator

```

```

        startN = G[u].second.begin(),
        endeN = G[u].second.end();
        while (startN != endeN) {
            Ziel << "%%EDGE:" << G[u].first.getGatterIdent() << ", "
5            << G[(startN).first].first.getGatterIdent() << "/0;" << endl;
            ++startN;
        }
        Ziel << "%%PROBSLIST" << endl << "%%END" << endl;
10    return os;
    }

#endif

15    #ifdef _KFGDefHeader

    #else

    #define _KFGDefHeader

20

    #include <string>

25    #include <iostream>

    using namespace std;

30

    typedef char StringT [256];

35

    class KFGDefC {
    private:

40

        StringT Def;

        int ScopeLevelD;

45    public:

        KFGDefC() { strcpy (Def, "-- unknown --");
                    ScopeLevelD = 0; };

50        KFGDefC(char _Def [], int _ScopeLevelD) { strcpy (Def, _Def);
                                                    ScopeLevelD =
            _ScopeLevelD; };

55        void setDef(char _Def []) { strcpy (Def, _Def); };

        char* getDef() { return Def; };

60        int getScopeLevelD() { return ScopeLevelD; };

        bool operator == (const KFGDefC& other) const { return ((strcmp(Def,
            other.Def) == 0)
65        & (ScopeLevelD
            == other.ScopeLevelD)); };

        bool operator != (const KFGDefC& other) const { return !(*this ==
70        other); };

        bool operator < (const KFGDefC& other) const { return (strcmp(Def,
            other.Def) < 0); };

75        bool operator > (const KFGDefC& other) const

```

T00001-03403650


```

                                                                    { return (strcmp(Def,
other.Def) > 0); };

        friend ostream& operator << ( ostream& os, const CFGDefC& Node);
5      };

#ifdefif

////////////////////////////////////
10 // Class for auxiliary list in order to produce a CFG therefrom.
// This class satisfies the nice-demands for the STL;
// i.e. the following is true for a class T:
// 0. It supports the copy constructor T (const T&),
// 1. the assignment operator T& operator= (const T&),
15 // 2. the comparison operator bool operator== (const T, &const T&) and
// 3. the unequal-to operator!=
// in such a way that:
// (a) { TRUE } T a(b) { a == b }
// (b) { TRUE } a = b { a == b }
20 // (c) { a == a }
// (d) { a == b <==> b == a }
// (e) { (a == b) AND ( b == c ) ==> (a == c) }
// (f) { a != b <==> NOT ( a== b ) };
//
25 // In addition, all functions, in particular getName, are equality preserving, i.e.
// (g) { a == b ==> a.getName() == b.getName() }
//
// (C) 1997 Siemens AG
////////////////////////////////////
30 // 1997-08-25 Andreas Steinhorst
////////////////////////////////////
#ifdef _KFGLineNodeHeader
#else
#define _KFGLineNodeHeader

35 #include <string>
#include <iostream>

using namespace std;

40 typedef char StringL [1000];

class KFGLineNodeC {
private:
45     StringL Name;
    int LineNumber;

public:
50     KFGLineNodeC() { strcpy (Name, "-- unknown --
    );
                                LineNumber = 0;
};
55     KFGLineNodeC(char _Name []) { strcpy (Name, _Name);
                                LineNumber =
0;};
    KFGLineNodeC(char _Name [], int _LineNumber) { strcpy (Name,
60     _Name);
                                LineNumber =
    _LineNumber; };

    void setName(char _Name []) { strcpy (Name, _Name); };
65     char* getName() { return Name; };
    int getLineNumber() { return LineNumber; };

    bool operator == (const KFGLineNodeC& other) const { return
70     ((strcmp(Name, other.Name) == 0)

```

TEXT - 640850

Variable	Mean	Standard Deviation	Minimum	Maximum
Age	34.5	10.2	22	55
Gender	0.5	0.5	0	1
Marital Status	0.6	0.5	0	1
Education	12.5	1.5	10	16
Income	3500	1500	1000	8000
Health	0.8	0.2	0	1
Smoking	0.3	0.5	0	1
Alcohol	0.2	0.4	0	1
Exercise	0.4	0.5	0	1
Stress	0.6	0.5	0	1
Sleep	0.7	0.3	0	1
Diet	0.5	0.5	0	1
Work	0.8	0.2	0	1
Family	0.6	0.5	0	1
Friends	0.7	0.4	0	1
Hobbies	0.5	0.5	0	1
Travel	0.4	0.5	0	1
Shopping	0.6	0.5	0	1
Reading	0.3	0.5	0	1
TV	0.7	0.4	0	1
Music	0.5	0.5	0	1
Gardening	0.4	0.5	0	1
Cooking	0.6	0.5	0	1
Cleaning	0.5	0.5	0	1
Driving	0.8	0.2	0	1
Volunteering	0.3	0.5	0	1
Religion	0.5	0.5	0	1
Politics	0.4	0.5	0	1
Environment	0.6	0.5	0	1
Technology	0.7	0.4	0	1
Art	0.3	0.5	0	1
Sports	0.5	0.5	0	1
Traveling	0.4	0.5	0	1
Learning	0.6	0.5	0	1
Working	0.8	0.2	0	1
Living	0.7	0.4	0	1
Feeling	0.6	0.5	0	1
Thinking	0.5	0.5	0	1
Acting	0.4	0.5	0	1
Reacting	0.6	0.5	0	1
Interacting	0.7	0.4	0	1
Communicating	0.8	0.2	0	1
Connecting	0.6	0.5	0	1
Engaging	0.5	0.5	0	1
Involving	0.4	0.5	0	1
Participating	0.6	0.5	0	1
Contributing	0.5	0.5	0	1
Supporting	0.4	0.5	0	1
Helping	0.6	0.5	0	1
Caring	0.7	0.4	0	1
Sharing	0.8	0.2	0	1
Giving	0.6	0.5	0	1
Receiving	0.5	0.5	0	1
Exchanging	0.4	0.5	0	1
Trading	0.6	0.5	0	1
Bartering	0.5	0.5	0	1
Dealing	0.4	0.5	0	1
Managing	0.6	0.5	0	1
Organizing	0.5	0.5	0	1
Planning	0.4	0.5	0	1
Executing	0.6	0.5	0	1
Implementing	0.5	0.5	0	1
Monitoring	0.4	0.5	0	1
Evaluating	0.6	0.5	0	1
Assessing	0.5	0.5	0	1
Measuring	0.4	0.5	0	1
Calculating	0.6	0.5	0	1
Counting	0.5	0.5	0	1
Measuring	0.4	0.5	0	1
Estimating	0.6	0.5	0	1
Approximating	0.5	0.5	0	1
Guessing	0.4	0.5	0	1
Assessing	0.6	0.5	0	1
Judging	0.5	0.5	0	1
Deciding	0.4	0.5	0	1
Choosing	0.6	0.5	0	1
Selecting	0.5	0.5	0	1
Optimizing	0.4	0.5	0	1
Maximizing	0.6	0.5	0	1
Minimizing	0.5	0.5	0	1
Reducing	0.4	0.5	0	1
Increasing	0.6	0.5	0	1
Expanding	0.5	0.5	0	1
Contracting	0.4	0.5	0	1
Shrinking	0.6	0.5	0	1
Reducing	0.5	0.5	0	1
Limiting				

[illegible]


```

5
(CodeLine, "--unknown--"); };

void setStatement(char _Statement [])
{ strcpy
(Statement, _Statement); };

void setCodeLine(char _CodeLine [])
{ strcpy
10 (CodeLine, _CodeLine); };

void setKFGKnotenNummer(int _KnotenNr)
{
KnotenNr = _KnotenNr; };

void setKnotenIdent (KnotenIdentT _KnotenIdent)
{
KnotenIdent = _KnotenIdent; };

20 int getKnotenNummer() { return KnotenNr; };

char* getStatement() { return Statement; };

char* getCodeLine() { return CodeLine; };
25 int getLevel() { return Level; };

int getNodeNr() { return NodeNr; };

30 int getLineNr() { return LineNr; };

KnotenIdentT getKnotenIdent() { return KnotenIdent; };

KFGNodeTypeT getKFGNodeType() { return KFGNodeType; };
35 bool operator == (const KFGLListNodeC& other) const
{ return
({strcmp(Statement, other.Statement) == 0)
&
40 (Level == other.Level)
&
(KFGNodeType == other.KFGNodeType)
&
(NodeNr == other.NodeNr) }); };

45 bool operator != (const KFGLListNodeC& other) const
{ return !(*this ==
other); };

50 bool operator < (const KFGLListNodeC& other) const
{ return
(strcmp(Statement, other.Statement) < 0); };

bool operator > (const KFGLListNodeC& other) const
{ return
55 (strcmp(Statement, other.Statement) > 0); };

friend ostream& operator << ( ostream& os, const KFGLListNodeC&
Node);
60 };
#endif
// #include <string>
// #include <iostream>
// #include "KFGLList.h"
65 // using namespace std;

// class KFGLListOpC : public KFGLListeC {
70 // public:

// void KFGLListOut(KFGLListeT & L)
// {
// KFGLListeT::iterator I = L.begin();
75 // while(I != L.end())

```

```

//          cout << *I++ << ' ';
//          cout << " size() = " << L.size() << endl;
//      }
//  };
5
//
//  //////////////////////////////////////
//  // Class for auxiliary list in order to produce a CFG therefrom.
10 // This class satisfies the nice-demands for the STL;
// i.e. the following is true for a class T:
// 0. It supports the copy constructor T (const T&),
// 1. the assignment operator T& operator= (const T&),
// 2. the comparison operator bool operator== (const T, &const T&) and
15 // 3. the unequal-to operator!=
// in such a way that:
// (a) { TRUE } T a(b) { a == b }
// (b) { TRUE } a = b { a == b }
// (c) { a == a }
20 // (d) { a == b <==> b == a }
// (e) { (a == b) AND ( b == c ) ==> (a == c) }
// (f) { a != b <==> NOT ( a == b ) };
//
//      In addition, all functions, in particular getName, are equality preserving,
25 // i.e.
// (g) { a == b ==> a.getName() == b.getName() }
//
// (C) 1997 Siemens AG
// 1997-08-25 Andreas Steinhorst
30 //
//  //////////////////////////////////////
#ifdef _KFGNodeHeader
#else
#define _KFGNodeHeader
35
#include <string>
#include <iostream>

using namespace std;
40
typedef char StringT [256];

class KFGNodeC {
private:
45
    StringT Name;
    int ScopeLevel;

public:
50
    KFGNodeC()
        { strcpy (Name, "-- unknown --
    "); ScopeLevel = 0;
        /* cout << "NodeC
    produced" << endl ; */};

55
    KFGNodeC(char _Name [] )
        { strcpy (Name, _Name);
        ScopeLevel = 0; };

    KFGNodeC(char _Name [], int _ScopeLevel)
        { strcpy (Name,
60
        _Name);
        ScopeLevel =
        _ScopeLevel;};

    void setName(char _Name []) { strcpy (Name, _Name); };
65
    char* getName() { return Name; };

    int getScopeLevel() { return ScopeLevel; };

70
    bool operator == (const KFGNodeC& other) const
        { return
        ((strcmp(Name, other.Name) == 0)
        &
        (ScopeLevel == other.ScopeLevel)); };
75
    bool operator != (const KFGNodeC& other) const

```

1997-08-25 Andreas Steinhorst

```

{ return
!(*this == other);    };

5         bool operator < (const KFGNodeC& other) const
        { return (strcmp(Name,
other.Name) < 0); };

        bool operator > (const KFGNodeC& other) const
10        { return (strcmp(Name,
other.Name) > 0); };

        friend ostream& operator << ( ostream& os, const KFGNodeC& Node);
    };
15
#endif

#ifdef _KFGNodeHeader
#else
20 ////////////////////////////////////////////////////////////////////
// Class for auxiliary list in order to produce a CFG therefrom.
// This class satisfies the nice-demands for the STL;
// i.e. the following is true for a class T:
// 0. It supports the copy constructor T (const T&),
25 // 1. the assignment operator T& operator= (const T&),
// 2. the comparison operator bool operator== (const T, &const T&) and
// 3. the unequal-to operator!=
// in such a way that:
// (a) { TRUE } T a(b) { a == b }
30 // (b) { TRUE } a = b { a == b }
// (c) { a == a }
// (d) { a == b <==> b == a }
// (e) { (a == b) AND ( b == c ) ==> (a == c) }
// (f) { a != b <==> NOT ( a== b ) };
35 //
// In addition, all functions, in particular getName, are equality preserving,
// i.e.
// (g) { a == b ==> a.getName() == b.getName() }
//
40 // (C) 1997 Siemens AG
//
//////////////////////////////////////////////////////////////////
// 1997-08-25 Andreas Steinhorst
//////////////////////////////////////////////////////////////////
45 #ifdef _KFGNodeHeader
#else
#define _KFGNodeHeader

#include <string>
50 #include <iostream>

using namespace std;

typedef char StringT [256];

55 class KFGListNodeC {
private:

    StringT Name;
    int ScopeLevel;
60     list <KFGUseC> Uses;
    list <KFGDefC> Defs;

public:
65     KFGListNodeC() { strcpy (Name,
"-- unknown --"); ScopeLevel = 0;
/* cout
<< "NodeC produced" << endl ; */};
70     KFGListNodeC(char _Name [] ) { strcpy (Name, _Name);
ScopeLevel = 0; };

    KFGListNodeC(char _Name [], int _ScopeLevel)
75     { strcpy (Name,
_Name);

```

```

ScopeLevel =
_ScopeLevel;};

void setName(char _Name []) { strcpy (Name, _Name); };

5 char* getName() { return Name; };

int getScopeLevel() { return ScopeLevel; };

10 bool operator == (const KFGLListNodeC& other) const
{ return ((strcmp(Name,
other.Name) == 0)
& (ScopeLevel
== other.ScopeLevel)); };

15 bool operator != (const KFGLListNodeC& other) const
{ return !(*this ==
other); };

20 bool operator < (const KFGLListNodeC& other) const
{ return (strcmp(Name,
other.Name) < 0); };

25 bool operator > (const KFGLListNodeC& other) const
{ return (strcmp(Name,
other.Name) > 0); };

friend ostream& operator << ( ostream& os, const KFGLListNodeC&
Node);
30 };

#endif

#ifdef _KFGNode1Header
35 #else
///////////////////////////////////////////////////////////////////
// Class for auxiliary list in order to produce a CFG therefrom.
// This class satisfies the nice-demands for the STL;
// i.e. the following is true for a class T:
40 // 0. It supports the copy constructor T (const T&),
// 1. the assignment operator T& operator= (const T&),
// 2. the comparison operator bool operator== (const T, &const T&) and
// 3. the unequal-to operator!=
// in such a way that:
45 // (a) { TRUE } T a(b) {a == b}
// (b) { TRUE } a = b {a == b}
// (c) { a == a}
// (d) { a == b <==> b == a }
// (e) { (a == b) AND ( b == c ) ==> (a == c) }
50 // (f) { a != b <==> NOT ( a== b) };
//
// In addition, all functions, in particular getName, are equality preserving,
// i.e.
// (g) { a == b ==> a.getName() == b.getName() }
55 //
// (C) 1997 Siemens AG
//
/////////////////////////////////////////////////////////////////
// 1997-08-25 Andreas Steinhorst
60 ///////////////////////////////////////////////////////////////////
#ifdef _KFGNode1Header
#else
#define _KFGNode1Header

65 #include <string>
#include <iostream>

using namespace std;

70 typedef char StringT [256];

class KFGLListNodeC {
private:

75 StringT Name;

```



```

        int ScopeLevel;
        list <KFGUseC> Uses;
        list <KFGDefC> Defs;

5         public:

            KFGListNodeC() { strcpy (Name,
"-- unknown --"); ScopeLevel = 0;
/* cout << "NodeC
10 produced" << endl ; */;

            KFGListNodeC(char _Name [] ) { strcpy (Name, _Name);
ScopeLevel = 0; };

15         KFGListNodeC(char _Name [], int _ScopeLevel)
{ strcpy (Name,
_Name);
ScopeLevel =
_ScopeLevel;};

20         void setName(char _Name []) { strcpy (Name, _Name); };

        char* getName() { return Name; };

25         int getScopeLevel() { return ScopeLevel; };

        bool operator == (const KFGListNodeC& other) const
{ return ((strcmp(Name,
30 other.Name) == 0)
& (ScopeLevel
== other.ScopeLevel)); };

        bool operator != (const KFGListNodeC& other) const
{ return !(*this ==
35 other); };

        bool operator < (const KFGListNodeC& other) const
{ return (strcmp(Name,
40 other.Name) < 0); };

        bool operator > (const KFGListNodeC& other) const
{ return (strcmp(Name,
other.Name) > 0); };

45         friend ostream& operator << ( ostream& os, const KFGListNodeC&
Node);
};

#endif

50         //Class for a list from STL. In this context, KFGListeC inherits all properties
//from the list created using STL list<KFGNodeC>.
#ifdef _KFGProgListHeader
#else
55 #define _KFGProgListHeader

#include <string>
#include <iostream>
#include <stdio.h>
60 #include <list>
#include <fstream>
#include <iterator>
#include "KFGListNode.h"

65         using namespace std;

        class KFGProgListC : public list<KFGListNodeC> {

70         public:

            KFGProgListC() {};

            //void KFGListeAusgeben();

75         //void KFGTokenListToKFGList ();

```

[illegible]

[illegible]

```

{ return !(*this ==
other); };

    bool operator < (const KFGTokenNodeC& other) const        { return
5  (strcmp(Name, other.Name) < 0); };

    bool operator > (const KFGTokenNodeC& other) const        { return
10 (strcmp(Name, other.Name) > 0); };

    friend ostream& operator << ( ostream& os, const KFGTokenNodeC&
Node);
};
15 #endif

#ifdef _KFGUseHeader

20 #else

#define _KFGUseHeader

25 #include <string>
#include <iostream>

using namespace std;
30 typedef char StringT [256];

class KFGUseC {
35 private:

    StringT Use;
40    int ScopeLevelU;

public:

45    KFGUseC()                { strcpy (Use, "-- unknown --");
                               ScopeLevelU = 0; };

    KFGUseC(char _Use [], int _ScopeLevelU)
                               { strcpy (Use, _Use);
50                               ScopeLevelU =
                               _ScopeLevelU; };

    void setUse(char _Use [])   { strcpy (Use, _Use); };

55    char* getUse()             { return Use; };

    int getScopeLevelU()       { return ScopeLevelU; };

    bool operator == (const KFGUseC& other) const
60 { return ((strcmp(Use,
other.Use) == 0)
                               & (ScopeLevelU
                               == other.ScopeLevelU)); };

65    bool operator != (const KFGUseC& other) const
    { return !(*this ==
other); };

```

TUEDEC 1999 10:50:50

Variable	Mean	SD	Min	Max
Age	38.5	10.5	25	55
Gender	1.0	0.0	0	1
Marital status	1.0	0.0	0	1
Education	12.5	1.5	9	15
Income	1.5	0.5	1	2
Occupation	1.0	0.0	0	1
Health status	1.0	0.0	0	1
Smoking status	1.0	0.0	0	1
Alcohol consumption	1.0	0.0	0	1
Exercise frequency	1.0	0.0	0	1
Stress level	1.0	0.0	0	1
Sleep quality	1.0	0.0	0	1
Appetite	1.0	0.0	0	1
Weight change	1.0	0.0	0	1
Blood pressure	1.0	0.0	0	1
Blood sugar	1.0	0.0	0	1
Cholesterol	1.0	0.0	0	1
Triglycerides	1.0	0.0	0	1
Hemoglobin A1c	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1
White blood cells	1.0	0.0	0	1
Platelets	1.0	0.0	0	1
Red blood cells	1.0	0.0	0	1
Hematocrit	1.0	0.0	0	1
Hemoglobin	1.0	0.0	0	1

```

        void checkLoopOrCond(SliceC & S1, SliceC::iterator SL1,
        SliceC::iterator SLORIG, int Pos1);

        void buildIn_D2_Part(SliceC & S1, int posOR_D2, SliceC::iterator
5      SL1, SliceC::iterator SLPUSE, int KnotenNrD2);

        int findD2Node(SliceC & S1, SliceC::iterator PUSE);

        int buildInIfTree(SliceC & S1, SliceC::iterator SLIF,
10     SliceC::iterator SLORIG, int pos1);

        SliceC::iterator lookForNextPUse(SliceC & S1, SliceC::iterator
        SNODE, SliceC::iterator SLPUSE);

15     void build_IFKF_Part(SliceC & S1, int posKFOR, SliceC::iterator
        SLPUSE);

        void build_A1_Part(SliceC & S1, int posIFDFOR, SliceC::iterator
        SLIF, SliceC::iterator SLORIG);

20     void buildD2_IFKF_Part(SliceC & S1, int posKFOR, SliceC::iterator
        SLPUSE);

        void buildD2_A1_Part(SliceC & S1, int posIFDFOR, SliceC::iterator
25     SLIF, SliceC::iterator SLNODE);

        int buildD2InIfTree(SliceC & S1, SliceC::iterator SLIF,
        SliceC::iterator SLORIG, int pos1);

30     void buildLoopKF_Part(SliceC & S1, int posAND_KF, int posLOOP_KF,
        int posD2, SliceC::iterator SLOOP);

        int buildIn_LoopKF_ANDPart(SliceC & S1, int posAND_KF,
        SliceC::iterator SLPUSE);

35     void buildIn_LoopKF_ORPart(SliceC & S1, int posAND_KF,
        SliceC::iterator SL1, int KnotenNrD2);

    };

40 #endif

#ifdef _uwgkanteC
#define _uwgkanteC

45 #include <iostream>

using namespace std;

50 class uwgkanteC {

public:
    short int folded;
    int Number;

55     uwgkanteC() {}

    uwgkanteC(int _Number) { Number = _Number; };

60     bool operator == (const uwgkanteC& other) const
        { return (Number == other.Number); };

    bool operator != (const uwgkanteC& other) const
        { return !(*this == other); };

65     bool operator < (const uwgkanteC& other) const
        { return (Number ==
        other.Number); };

70     bool operator > (const uwgkanteC& other) const
        { return (Number == other.Number); };

    friend ostream& operator << ( ostream& os, const uwgkanteC& Node);

    };

75 #endif

```

F0001-00000000

```

#ifndef _uwgknotenC
#define _uwgknotenC

#include <iostream>

5   const int maxKnotentextLength=128;
    const int maxBemerkLength=1000;
    const int maxWahrVarLength=16;

10  typedef struct ww {
        short int Wert;
        struct ww *next;
        } TMCSWert;

15  typedef struct el {
        struct ftgatter* unabElement;
        struct ww *next;
        struct el *nextel;
20      } TMinSet;

    typedef enum {AND, OR, CAUSE, EFFECT, NOT} NodeIdentT;

    using namespace std;

25  class uwgknotenC {

    public:
        static int DummyNr;
        int GatterIdent;
        int outof;
        int CauseNr;
        char gattertext[maxKnotentextLength];
        char gatterbemerkung[maxBemerkLength];
35      double wahrsch;
        char wahrvar[maxWahrVarLength];
        NodeIdentT NodeIdent;

        uwgknotenC() { NodeIdent = EFFECT;

40      CauseNr = 0;
        "-- unknown --";
        strcpy (gattertext,
        strcpy (gatter-

45      bemerkung, "--none--");
        GatterIdent = DummyNr++; };

        uwgknotenC(NodeIdentT _NodeIdent)
50      {
        NodeIdent = _NodeIdent;
        CauseNr = 0;

55      strcpy(gattertext, "-- unknown --");
        strcpy(gatterbemerkung, "--none--");
        GatterIdent = DummyNr++; };

        uwgknotenC(NodeIdentT _NodeIdent, int _CauseNr/*, char
        _gattertext[]*/)
60      {
        NodeIdent = _NodeIdent;

65      CauseNr = _CauseNr;
        strcpy(gattertext, "-- unknown --");

70      strcpy(gatterbemerkung, "--none--");
        /*strcpy(gattertext, _gattertext);*/
        DummyNr++; };

75
    GatterIdent =

```

F00021-63403550

```

1      uwgknotenC(NodeIdT _NodeId, int _CauseNr, char _gattertext[],
      char _gatterbemerkung[])
      { NodeId =
      _NodeId;
      CauseNr =
      _CauseNr;
      strcpy(gattertext, "-- unknown --");
10     strcpy(gattertext, _gattertext);
      strcpy(gatterbemerkung, _gatterbemerkung);
      GatterId =
      DummyNr++; };

15     uwgknotenC(NodeIdT _NodeId, int _CauseNr, char _gattertext[])
      { NodeId =
      _NodeId;
      CauseNr =
      _CauseNr;
20     strcpy(gattertext, "-- unknown --");
      strcpy(gattertext, _gattertext);
25     strcpy(gatterbemerkung, "--none--");
      GatterId =
      DummyNr++; };

30     uwgknotenC(NodeIdT _NodeId, char _gattertext[], char
      _gatterbemerkung[])
      { NodeId =
      _NodeId;
      CauseNr = 0;
35     strcpy(gattertext, _gattertext);
      strcpy(gatterbemerkung, _gatterbemerkung);
      GatterId =
      DummyNr++; };

40     uwgknotenC(NodeIdT _NodeId, char _gattertext[])
      { NodeId =
      _NodeId;
      CauseNr = 0;
45     strcpy(gattertext, _gattertext);
      strcpy(gatterbemerkung, "--none--");
      GatterId =
      DummyNr++; };

      int getCauseNr()      { return CauseNr; };
      int getGatterId()      { return GatterId; };
55     NodeIdT getNodeId() const      { return NodeId; };

      bool operator == (const uwgknotenC& other) const
      { return ((CauseNr ==
60     other.CauseNr)
      &
      (NodeId == other.NodeId)
      &
      (strcmp(gattertext, other.gattertext) == 0)
65     other.GatterId) * /); };

      bool operator != (const uwgknotenC& other) const
      { return !(*this ==
70     other); };

      bool operator < (const uwgknotenC& other) const
      { return (GatterId <
      other.GatterId); };

75     bool operator > (const uwgknotenC& other) const

```



```

{ return
(GatterIdent > other.GatterIdent); };

friend ostream& operator << ( ostream& os, const uwgknotenC& Node);
5   };
   #endif
10  #include "AS_GraphKante.h"
   #include <iostream>

      ostream& operator << ( ostream& os, const GraphKanteC & Kante){
      os << Kante.KantenTyp;
15      return os;
      }

   #include "AS_GraphNode.h"
20  #include <iostream>

      ostream& operator << ( ostream& os, const GraphNodeC& Node){
      os << endl << Node.NodeNr;
      return os;
25      }

   #include "AS_Slice.h"
30  #include <iostream>

   #include <iterator>

   #include <algorithm>
35  #include "uwggraph.h"

   using namespace std;

40  //F0: Function for selecting the variable for which an error tree is to be created.

   // A pointer to the selected node is returned.
   KFGListC::iterator SliceC::defineVariableToSlice(KFGListC & L2) {
45     int Number = 0;
     KFGListC::iterator KFGI = L2.begin();
     KFGListC::iterator VARDEFI = L2.begin();
     KFGUListC::iterator USEIT;
     while ( KFGI != L2.end()) {
50         USEIT = KFGI->Uses.begin();
         if ( KFGI->getKFGNodeType() == OP ) {
             cout << KFGI->getKnotenNummer() << ": " << USEIT->getUse()
<< endl;;
         }
55         KFGI++;
     }
     cout << "Enter the node number and press RETURN: ";
     cin >> Number;
     while ( KFGI != L2.begin()) {
60         if (KFGI->getKnotenNummer() == Number) {
             VARDEFI = KFGI;
         }
         KFGI--;
     }
65     if (VARDEFI->getKFGNodeType() == OP) {
         cout << "The selected node was No: " << VARDEFI->getKnotenNummer()
<< endl;

```


[illegible]

```

        dummyIf = 0;
    }
    if (HELPDEF->getKFGNodeType() == NO) {
        DEFIT = HELPDEF->Defs.begin();
5       if (strcmp(DEFIT->getDef(), PUSEIT->getUse()) == 0) {
            HELPDEFRETURN = HELPDEF;
            dummy = 1;
        }
    }
10    }
    if ((HELPDEF == L1.begin()) && (HELPDEF->getKFGNodeType() == NO)) {
        DEFIT = HELPDEF->Defs.begin();
        if (strcmp(DEFIT->getDef(), PUSEIT->getUse()) == 0) {
15            HELPDEFRETURN = HELPDEF;
            dummy = 1;
        }
    }
    //find the outermost loop if it actually exists.
    if (ITER->getLevel() > 2) {
20        while ((HELPIT != L1.end()) && (dummy1 != 1)) {
            HELPIT++;
            if ((HELPIT->getKFGNodeType() == EL) && (HELPIT->getLevel()
< AktLevel)) {
25                HELPLOOP = HELPIT;
                if (HELPIT->getLevel() > 2) {
                    AktLevel = HELPIT->getLevel();
                }
                else {
30                    dummy1 = 1;
                }
            }
        }
        HELPIT = HELPLOOP;
        //go to the start of the outermost loop:
35        while ((HELPIT->getKFGNodeType() != LC) || (HELPIT->getLevel() !=
HELPLoop->getLevel())) {
            HELPIT--;
        }
        //if the def node found is outside the outermost loop and
        //its ScopeLevel is greater than that for the outermost loop, look
        //for whether there is still another def node further up.
        if (HELPDEF->getNodeNr() > HELPIT->getNodeNr()) {
            if (HELPDEF->getLevel() >= HELPIT->getLevel()) {
45                dummy = 0;
                while ((HELPDEF != L1.begin()) && (dummy != 1)) {
                    HELPDEF--;
                    DEFIT = HELPDEF->Defs.begin();
                    if (strcmp(DEFIT->getDef(), PUSEIT->getUse())
== 0) {
50                        HELPDEFRETURN = HELPDEF;
                        dummy = 1;
                    }
                }
            }
        }
55    }
    return HELPDEFRETURN;
}

60 //F6: Function looks, on the basis of the upper end, for the lower end of the
//    range by needing to look for the defs.
//    An iterator for the lower limit is returned.
KFGListC::iterator SliceC::findLowerLimit(KFGListC & L1, KFGListC::iterator ITER,
KFGListC::iterator UPPERLIMIT) {
65     int dummy1 = 0;
     int AktLevel = 0;
     KFGListC::iterator HELPIT = ITER;
     KFGListC::iterator HELPLOOP = ITER;
     KFGListC::iterator LOWERLIMIT = ITER;
70     AktLevel = ITER->getLevel();
     if (ITER->getKFGNodeType() == LC) {
         while ((HELPLoop->getKFGNodeType() != EL) || (HELPLoop->getLevel()
!= AktLevel)) {
75             HELPLOOP++;
         }
     }

```

```
}  
//find the end of the outermost loop.
```

FOOTNOTES

```

    if (ITER->getLevel() > 2) {
        while ((HELPIT != L1.end()) && (dummy1 != 1)) {
            HELPIT++;
            if ((HELPIT->getKFGNodeType() == EL) && (HELPIT->getLevel()
5      < AktLevel)) {
                HELPLOOP = HELPIT;
                if (HELPIT->getLevel() > 2) {
                    AktLevel = HELPIT->getLevel();
                }
            }
            else {
10              dummy1 = 1;
            }
        }
    }
    HELPIT = HELPLOOP; //HELPLOOP points to the end
15  of the outermost loop, otherwise it points to the p-use.
    while ((HELPIT->getKFGNodeType() != LC) || (HELPIT->getLevel() !=
        HELPLOOP->getLevel())) {
        HELPIT--; //HELPIT points
20  to the start of the outermost loop.
        if (HELPIT->getNodeNr() < UPPERLIMIT->getNodeNr()) {
            LOWERLIMIT = HELPLOOP; //if the upper limit is outside the
25  loops.
        }
        else {
            AktLevel = UPPERLIMIT->getLevel();
            while ((HELPLOOP->getKFGNodeType() != EL) || (HELPLOOP->
30  >getLevel() <= AktLevel)) {
                HELPLOOP--;
                LOWERLIMIT = HELPLOOP; //if the upper limit is inside the
loop.
            }
        }
        else {
35          LOWERLIMIT = HELPLOOP;
        }
        return LOWERLIMIT;
    }
40  }

//F3: Function draws a KFK from the P-Use to all C-Uses which are at the same
// loop or branch level.
// input: iterator for P-Use node.
45  void SliceC::KFKPUseToCUse(KFGListC::iterator PUSEIT, int SchleifenEnde) {
    SliceC::iterator SL1 = begin();
    SliceC::iterator SLHELP = begin();
    KFGListC::iterator ITER = PUSEIT;
    KFGUseListC::iterator USEIT;
50  KFGP_UseListC::iterator PUSEIT2;
    KFGUseListC::iterator CUSEIT2;
    int KnotenLevel;
    int KnotenNummer;
    KnotenNummer = PUSEIT->getNodeNr();
    KnotenLevel = PUSEIT->getLevel();
55  while ((*SL1).first.getNodeNr() != KnotenNummer)
        SL1++;
    SLHELP = SL1;
    SL1 = begin();
60  while (SL1 != end()) {
        if ((KnotenNummer > (*SL1).first.getNodeNr()) && (SchleifenEnde <
(*SL1).first.getNodeNr())) {
            if ((*SL1).first.getKFGNodeType() == NO) &&
            ((*SL1).first.getLevel() == KnotenLevel)) {
65              //insert((*SLHELP).first, (*SL1).first, KFK);
              insert((*SL1).first, (*SLHELP).first, KFK); //the
reverse direction of the edge so that each node knows its predecessor.
              //cout << "eingefügterKnotenF3: " <<
              (*SL1).first.getNodeNr() << endl;
70              //cout << "eingefügterKnotenF3: " <<
              (*SLHELP).first.getNodeNr() << endl;
            }
        }
        SL1++;
75  }
}

```



```

HLevel = ITER->getLevel();
//Is the c-use node in a loop?
if (ITER->getLevel() >= 2) {
    while ((HELPIT != L1.end()) && (dummy != 1)) {
5         HELPIT++;
        if ((HELPIT->getKFGNodeType() == EL) && (HELPIT->getLevel()
<= HLevel)) {
            HELPLOOP = HELPIT;
            if (HELPIT->getLevel() > 2) {
10                 HLevel--;
            }
            else {
                dummy = 1;
            }
15        }
    }
    //The iterator HELPLOOP now points to the end of the outermost loop,
    surrounding the node,
20    //if this loop exists, otherwise the iterator points to the c-use node
    itself.
    if (HELPLOOP != ITER) {
        HELPIT = HELPLOOP;           //Iterator points to the end of the
        outermost loop.
25        while ((HELPIT->getKFGNodeType() != LC) || (HELPIT->getLevel() !=
        HELPLOOP->getLevel())) {
            HELPIT--;
        }
        if (HELPIT->getNodeNr() < UPPERLIMIT->getNodeNr()) {
30            LOWERLIMIT = HELPLOOP; //upper limit outside the outermost
            loop;
        }
        else if (ITER->getLevel() == UPPERLIMIT->getLevel()) {
            LOWERLIMIT = ITER;           //upper limit with the c-use
35        in the same loop;
        }
        else if (ITER->getLevel() < UPPERLIMIT->getLevel()) {
            LOWERLIMIT = HELPLOOP; //upper limit in the same outer loop
40        but
        }
        //inside in
        another loop, which is before the c-use;
        else {
            HLevel = UPPERLIMIT->getLevel();
            while ((HELPLOOP->getKFGNodeType() != EL) || (HELPLOOP->
45        >getLevel() <= HLevel)) {
                HELPLOOP--;
            }
            LOWERLIMIT = HELPLOOP; //upper limit in a lower loop than the
            c-use;
50        }
        else {
            LOWERLIMIT = ITER;           //no outer loop present.
            return LOWERLIMIT;
55    }

//F7: Function looks for the upper limit up to which defs for a c-use can be
sought. This
// works in a similar way to the corresponding function for p-uses.
60    KFGListC::iterator SliceC::findUpperLimitFromCUse(KFGListC & L1, KFGListC::iterator
    ITER1, KFGUSeListC::iterator USEIT) {
        int dummy = 0;
        int dummy1 = 0;
        int dummyIf = 0;
65        int AktLevel = 0;
        KFGListC::iterator HELPDEF = ITER1;
        KFGListC::iterator HELPLOOP = ITER1;
        KFGListC::iterator HELPIT = ITER1;
        KFGListC::iterator HELPIF = ITER1;
70        KFGListC::iterator HELPDEFRETURN = ITER1;
        KFGDefListC::iterator DEFIT;
        AktLevel = ITER1->getLevel();
        //cout << "processing node: " << ITER1->getNodeNr() << endl;
        //find the first above the use.
75        do {
            if (HELPLOOP->getKFGNodeType() == EEL) {
                dummyIf = 1;

```



```

    }
    if ((HELPDEF->getKFGNodeType() == ETh) && (HELPDEF->getLevel() <=
ITER1->getLevel()) && (dummyIf == 0)) {
        HELPIF = HELPDEF;
5      while ((HELPDEF->getKFGNodeType() != IFC) || (HELPDEF-
>getLevel() != HELPIF->getLevel())) {
            HELPDEF--;
        }
        dummyIf = 0;
10    }
    if (HELPDEF->getKFGNodeType() == NO) {
        DEFIT = HELPDEF->Defs.begin();
        if (strcmp(DEFIT->getDef(), USEIT->getUse()) == 0) {
            HELPDEFRETURN = HELPDEF;
15          if (HELPDEF != ITER1) {
                dummy = 1;
            }
        }
    }
    HELPDEF--;
20  } while ((HELPDEF != L1.begin()) && (dummy != 1));
    if ((HELPDEF == L1.begin()) && (HELPDEF->getKFGNodeType() == NO)) {
        DEFIT = HELPDEF->Defs.begin();
        if (strcmp(DEFIT->getDef(), USEIT->getUse()) == 0) {
25          HELPDEFRETURN = HELPDEF;
        }
    }
    HELPDEF = HELPDEFRETURN;
    //cout << "first def: " << HELPDEFRETURN->getNodeNr() << endl;
30  //find the outermost loop if it actually exists.
    if (ITER1->getLevel() >= 2) {
        while ((HELPIT != L1.end()) && (dummy1 != 1)) {
            HELPIT++;
            if ((HELPIT->getKFGNodeType() == EL) && (HELPIT->getLevel()
35 <= AktLevel)) {
                HELPLOOP = HELPIT;
                if (HELPIT->getLevel() > 2) {
                    AktLevel--;
                }
40              else {
                    dummy1 = 1;
                }
            }
        }
        HELPIT = HELPLOOP;
45      //cout << "End of the outermost loop: " << HELPIT->getNodeNr() <<
endl;
        //go to the start of the outermost loop if it exists;
        if (HELPLOOP->getKFGNodeType() == EL) {
50          while ((HELPIT->getKFGNodeType() != LC) || (HELPIT-
>getLevel() != HELPLOOP->getLevel())) {
                HELPIT--;
            }
            //cout << "Start of the outermost loop: " << HELPIT-
55 >getNodeNr() << endl;
            //if the def node found is outside the outermost loop and
            //its ScopeLevel is greater than that for the outermost
            loop, look for whether
            //there is still another def node further up.
            if (HELPDEF->getNodeNr() > HELPIT->getNodeNr()) {
60              if (HELPDEF->getLevel() >= HELPIT->getLevel()) {
                    dummy = 0;
                    while ((HELPDEF != L1.begin()) && (dummy !=
65 1)) {
                        HELPDEF--;
                        DEFIT = HELPDEF->Defs.begin();
                        if (strcmp(DEFIT->getDef(), USEIT-
>getUse()) == 0) {
70                            HELPDEFRETURN = HELPDEF;
                            dummy = 1;
                        }
                    }
                }
            }
        }
        //c-use within the outermost loop;
75      else {

```



```

HELPDEF--;
DEFIT = HELPDEF->Defs.begin();
if (strcmp(DEFIT->getDef(),USEIT-
>getUse()) == 0) {
5
    HELPDEFRETURN = HELPDEF;
}
}
}
}
10
    //c-use not in a loop, but in a branch;
    else {
        if (HELPDEF->getLevel() > ITER1->getLevel()) {
            dummy = 0;
15
            while ((HELPDEF != L1.begin()) && (dummy != 1)) {
                HELPDEF--;
                DEFIT = HELPDEF->Defs.begin();
                if (strcmp(DEFIT->getDef(),USEIT->getUse())
== 0) {
20
                    HELPDEFRETURN = HELPDEF;
                    dummy = 1;
                }
            }
        }
    }
25
}
//c-use not in a loop;
else {
    if (HELPDEF->getLevel() > ITER1->getLevel()) {
30
        dummy = 0;
        while ((HELPDEF != L1.begin()) && (dummy != 1)) {
            HELPDEF--;
            DEFIT = HELPDEF->Defs.begin();
            if (strcmp(DEFIT->getDef(),USEIT->getUse()) == 0) {
35
                HELPDEFRETURN = HELPDEF;
                dummy = 1;
            }
        }
    }
40
}
//cout << "UpperLimitFunktion: " << HELPDEFRETURN->getNodeNr() << endl;
return HELPDEFRETURN;
}

45
//F9: Function checks whether there is already a node in
the slice.
If there is, a one is returned, otherwise a zero is returned.
// input: node number of the node sought;
// output: integer value 0 or 1;
50
int SliceC::checkForNodes(int NodeNumber) {
    int dummy = 0;
    SliceC::iterator SL1 = begin();
    while ((SL1 != end()) && (dummy != 1)) {
55
        if ((*SL1).first.getNodeNr() == NodeNumber) {
            dummy = 1;
        }
        SL1++;
    }
    if (dummy == 1) {
60
        return 1;
    }
    else {
        return 0;
65
    }
}

//F10: Function examines whether there is a def in a loop; if there is,
// function F1, which looks for the p-use, is called. This first checks whether
70
the p-use found is already present in the slice.
void SliceC::defInLoop(KFGListC & L1, KFGListC::iterator ITER) {
    int dummyLoop = 0;
    KFGListC::iterator HELPIT = ITER;
    while ((HELPIT != L1.begin()) && (dummyLoop != 1)) {
75
        HELPIT--;
        if (((HELPIT->getKFGNodeType() == LC) || (HELPIT->getKFGNodeType()

```

F000001-00000000


```

dummyLoop = 1;
    }
}

//F11: The selected start node for the slice is transferred to the function,
// and the function investigates whether this node is in a loop; if it is,
// the function "sliceForLoops" is first called, otherwise "findDefToCUse" is
// called immediately.
void SliceC::startBuildSlice(KFGListC & L1/*, KFGListC::iterator OUTPUTIT*/) {
    int dummyNode = 0;
    KFGListC::iterator STARTVARI = defineVariableToSlice(L1);
    KFGListC::iterator HELPOUT = STARTVARI;
    while ((HELPOUT != L1.begin()) && (dummyNode != 1)) {
        HELPOUT--;
        if ((HELPOUT->getKFGNodeType() == LC) || (HELPOUT->getKFGNodeType()
            == IFC))
            && (HELPOUT->getLevel() == STARTVARI->getLevel())) {
                sliceForLoops(L1, STARTVARI);
                dummyNode = 1;
            }
    }
    //cout << "F11" << OUTPUTIT->getNodeNr() << endl;
    findDefToCUse(L1, STARTVARI);
}

void SliceC::sliceAusgeben() {
    ofstream Ziel("Slice2.slc");
    ostream_iterator<KFGListNodeC> POSIT(Ziel, "\n");
    //ostream_iterator<KFGListNodeC> POSIT2(Ziel, "\n");
    SliceC::iterator SLC = begin();
    while (SLC != end()) {
        *POSIT++ = (*SLC).first;
        SliceC::Nachfolger::iterator IT = (*SLC).second.begin();
        SliceC::Nachfolger::iterator ITEND = (*SLC).second.end();
        while (IT != ITEND) {
            //a = (*IT).first;
            *POSIT++ = SLC[(*IT).first].first;
            *IT++;
        }
        ++SLC;
    }
}

#include "KFGDef.h"
#include <iostream>

ostream& operator << (ostream& os, const KFGDefC& Node){
    os << "DEF:          " << Node.Def << "          " << Node.ScopeLevelD;

    return os;
}

#include "KFGLineNode.h"
#include <iostream>

ostream& operator << (ostream& os, const KFGLineNodeC& Node){
    os << Node.Name << " " << Node.LineNumber << endl;
    return os;
}

//Function which constructs a CFG from KFGTokenList.

```

```

#include <iostream>

#include "KFGList.h"

5  #include "KFGTokenList.h"
   #include "KFGUse.h"
   #include "KFGDef.h"
   #include "KFGProgList.h"
   #include <algorithm>

10

void KFGListC::TokenList2KFGList(KFGTokenListC & L1) {
    int dummy;
    KFGTokenListC::iterator TLI = L1.end();
15    KFGP_UseListC::iterator P_USEI;
    KFGUseListC::iterator USEI;
    dummy = 0;
    //while (strcmp(TLI->getName(),"main") != 0) {
    while ((TLI != L1.begin()) && (dummy != 1)) {
20        if (TLI->getTokenNodeType() == N) {
            if (strcmp(TLI->getName(),"main") == 0) {
                dummy = 1;
            }
        }
        //TLI++;
        switch (TLI->getTokenNodeType()) {
25            case PL:
                {
                    TLI--;
                    KFGListNodeC hN1("NORMAL",NO,TLI->getScopeLevel(),
30                    TLI->getLineNumber();
                    hN1.Defs.push_back(KFGDefC(TLI->getName(),TLI->
                    >getScopeLevel()));
                    push_front(hN1);
                    TLI--;
35                }
                break;
            /*case IF:
                push_front(KFGListNodeC("IF",IFC,TLI->getScopeLevel()));
                TLI--;
                break;*/
            case BT:
                //push_front(KFGListNodeC("BT",BTh,TLI->getScopeLevel()));
                {
45                    TLI--;
                    //KFGP_UseListC::iterator P_USEI;
                    KFGListNodeC hN1("IFCOND",IFC,TLI->getScopeLevel(),
                    TLI->getLineNumber();
                    while (TLI->getTokenNodeType() != IF) {
50                        KFGUseC hUset(TLI->getName(),TLI->
                        getScopeLevel());
                        P_USEI =
                        find(hN1.P_Uses.begin(),hN1.P_Uses.end(),hUset);
                        if (P_USEI == hN1.P_Uses.end()) {
55                            hN1.P_Uses.push_back(hUset);
                            Anzahl_P_Uses++;
                        }
                        //hN1.P_Uses.push_back(KFGUseC(TLI->
                        getName(),TLI->getScopeLevel()));
60                        TLI--;
                    }
                    push_front(hN1);
                    Entscheidungen++;
                }
                break;
65            case ET:
                push_front(KFGListNodeC("ENDTHEN",ETTh,TLI->
                getScopeLevel()));
                TLI--;
                break;
70            case BE:
                push_front(KFGListNodeC("BEGINELSE",BEL,TLI->
                getScopeLevel()));
                TLI--;
                break;
75            case EE:

```

```
getScopeLevel());
push_front(KFGListNodeC("ENDELSE",EEL,TLI->
5      /*case WHILE:
      TLI--;
      break;
      push_front(KFGListNodeC("WHILE",LC,TLI->getScopeLevel()));
```

TOGETHER - 6340360

```

    TLI--;
    break;*/
    case BW:
        //push_front(KFGListNodeC("BW", BL, TLI->getScopeLevel()));
        {
            TLI--;
            //KFGP_UseListC::iterator P_USEI;
            KFGListNodeC hN1("LOOPCOND", LC, TLI->getScopeLevel(),
TLI->getLineNumber());
            while (TLI->getTokenNodeType() != WHILE) {
                KFGUseC hUset(TLI->getName(), TLI->
getScopeLevel());
                P_USEI =
find(hN1.P_Uses.begin(), hN1.P_Uses.end(), hUset);
                if (P_USEI == hN1.P_Uses.end()) {
                    hN1.P_Uses.push_back(hUset);
                    Anzahl_P_Uses++;
                }
                //hN1.P_Uses.push_back(KFGUseC(TLI->
20 getName(), TLI->getScopeLevel()));
                TLI--;
            }
            push_front(hN1);
            Schleifenentscheidungen++;
        }
        break;
    case EW:
        push_front(KFGListNodeC("ENDLOOP", EL, TLI->getScopeLevel()));
        TLI--;
        break;
    case BDOW:
        {
            TLI--;
            KFGListNodeC hN1("DOWHILELOOPCOND", DOWLC, TLI->
35 getScopeLevel(), TLI->getLineNumber());
            while (TLI->getTokenNodeType() != DOWS) {
                KFGUseC hUset(TLI->getName(), TLI->
>getScopeLevel());
                P_USEI =
40 find(hN1.P_Uses.begin(), hN1.P_Uses.end(), hUset);
                if (P_USEI == hN1.P_Uses.end()) {
                    hN1.P_Uses.push_back(hUset);
                    Anzahl_P_Uses++;
                }
                hN1.P_Uses.push_back(KFGUseC(TLI->
45 >getName(), TLI->getScopeLevel()));
                TLI--;
            }
            push_front(hN1);
        }
        break;
    case DO:
        push_front(KFGListNodeC("DOWHILELOOP", DOWL, TLI->
getScopeLevel()));
        TLI--;
        Schleifenentscheidungen++;
        break;
    case EF:
        {
            //TLI--;
            int HLevel;
            HLevel = TLI->getScopeLevel();
            push_front(KFGListNodeC("ENDLOOP", EL, TLI->
getScopeLevel()));
            //while (TLI->getTokenNodeType() != BF) {
            while ((TLI->getTokenNodeType() != BF) || (TLI->
65 >getScopeLevel() != HLevel)) {
                TLI--;
            }
            TLI--;
            if (TLI->getTokenNodeType() == PF)
                TLI--;
            KFGListNodeC hN1("NORMAL", NO, TLI->getScopeLevel(),
70 TLI->getLineNumber());
            hN1.Defs.push_back(KFGDefC(TLI->getName(), TLI->
>getScopeLevel()));

```



```

        Anzahl_Defs++;
        hN1.Uses.push_back(KFGUseC(TLI->getName(), TLI->
getScopeLevel()));

```

5

```
Anzahl_Uses++;
push_front(hN1);
//while (TLI->getTokenNodeType() != EF) {
```

[illegible]


```

5      getName(), TLI->getScopeLevel());
      TLI--;
      Anzahl_Defs++;
      if (TLI->getTokenNodeType() == N) {
          helpNode1.Defs.pop_front();
          Anzahl_Defs--;
          //in
      }
      this is an array and
      //hence the last node needs to be deleted again.
10     TLI++;
      //For this, the deleted node needs to be entered into the Use list.
      KFGUseC hUse2(TLI->getName(), TLI->
      getScopeLevel());
      USEI =
15     find(helpNode1.Uses.begin(), helpNode1.Uses.end(), hUse2);
      if (USEI == helpNode1.Uses.end()) {
          helpNode1.Uses.push_back(hUse2);
          Anzahl_Uses++;
      }
20     TLI--;
      helpNode1.Defs.push_back(KFGDefC(TLI->
      >getName(), TLI->getScopeLevel()));
      helpNode1.Uses.push_back(KFGUseC(TLI->
      >getName(), TLI->getScopeLevel()));
25     Anzahl_Defs++;
      Anzahl_Uses++;
      TLI--;
      }
      }
30     push_front(helpNode1);
      }
      //produce node which contains only Defs;
      else if (TLI->getTokenNodeType() == DEF) {
          TLI--;
35     KFGListNodeC helpNode1("NORMAL", NO, TLI->
      getScopeLevel(), TLI->getLineNumber());
      helpNode1.Defs.push_back(KFGDefC(TLI->getName(), TLI->
      >getScopeLevel()));
      push_front(helpNode1);
40     Anzahl_Defs++;
      TLI--;
      }
      else if (TLI->getTokenNodeType() == PF) {
          TLI--;
45     KFGListNodeC hN1("NORMAL", NO, TLI->getScopeLevel(),
      TLI->getLineNumber());
      hN1.Defs.push_back(KFGDefC(TLI->getName(), TLI->
      >getScopeLevel()));
      hN1.Uses.push_back(KFGUseC(TLI->getName(), TLI->
      >getScopeLevel()));
50     push_front(hN1);
      Anzahl_Defs++;
      Anzahl_Uses++;
      }
55     //produce node which contains output variables;
      else {
          TLI--;
          KFGListNodeC helpNode1("OUTPUT", OP, TLI->
      getScopeLevel(), TLI->getLineNumber());
      helpNode1.Uses.push_back(KFGUseC(TLI->getName(), TLI->
      >getScopeLevel()));
      push_front(helpNode1);
      Anzahl_Uses++;
      TLI--;
65     }
      Anweisungen++;
      break;
      default:
          TLI--;
70     }
      }
      KnotenNummern();
      KFGListC::iterator KFG = begin();
      KnotenIdentifizierer(KFG);
      addLineInToList();
75

```

```

Anzahl_Deklarationen = zaehleDeklarationen(L1);
}

```

[illegible]

```

void KFGListC::KnotenNummern() {
    int KnotenNr = 1;
    KFGListC::iterator KFG1 = begin();
    while (KFG1 != end()) {
5       if ((KFG1->getKFGNodeType() == EL) || (KFG1->getKFGNodeType() ==
      ETh) || (KFG1->getKFGNodeType() == BE1) || (KFG1->getKFGNodeType() == BE1)) {
          KFG1++;
      }
      else {
10         KFG1->setKFGKnotenNumber(KnotenNr);
            KnotenNr++;
            KFG1++;
      }
15 }

void KFGListC::KnotenIdentifizierer(KFGListC::iterator KFG) {
    int LOOPLevel = 0;
    int THENLevel = 0;
    int ELSELevel = 0;
    KFGListC::iterator KFG1 = KFG;
    KFGListC::iterator LOOPIT = KFG;
    KFGListC::iterator IFIT = KFG;
    KFGListC::iterator ELSEIT = KFG;
25    while (KFG1 != end()) {
        switch(KFG1->getKFGNodeType()) {
            case LC:
30                 {
                    LOOPLevel = KFG1->getLevel();
                    KFG1++;
                    LOOPIT = KFG1;
                    while ((KFG1->getKFGNodeType() != EL) || (KFG1-
35 >getLevel() != LOOPLevel)) {
                        KFG1->setKnotenIdent(L0OP);
                        KFG1++;
                    }
                    KnotenIdentifizierer(LOOPIT);
                }
                break;
40             case IFC:
                {
                    THENLevel = KFG1->getLevel();
                    KFG1++;
                    IFIT = KFG1;
                    while ((KFG1->getKFGNodeType() != ETh) || (KFG1-
45 >getLevel() != THENLevel)) {
                        KFG1->setKnotenIdent(THEN);
                        KFG1++;
                    }
                    KnotenIdentifizierer(IFIT);
                }
                break;
55             case BE1:
                {
                    ELSELevel = KFG1->getLevel();
                    KFG1++;
                    ELSEIT = KFG1;
                    while ((KFG1->getKFGNodeType() != BE1) || (KFG1-
60 >getLevel() != ELSELevel)) {
                        KFG1->setKnotenIdent(ELSE);
                        KFG1++;
                    }
                    KnotenIdentifizierer(ELSEIT);
                }
                break;
65             default:
                {
                    //cout << "Ouch" << endl;
                    KFG1++;
70             }
            //KFG1++;
        }
    }
}

```

p.0001 = 6400350

```

void KFGListC::addLineInToList() {
    int zahl;
    char line[256];
    KFGProgListC LP;
    ifstream datei("CodeLine.dat");
    if (!datei) {
        cout << "FAULT: Cannot open file 'CodeLine.dat'." << endl;
    }
    else {
        while (!datei.eof()) {
            datei.getline(line, 255, '\n');
            for (int i=0; i<strlen(line); i++) {
                if (line[i] == '"') {
                    line[i] = '\\';
                }
                if (line[i] == '{') {
                    line[i] = ';';
                }
            }
            zahl = atoi(line);
            KFGLineNodeC hknoten(line,zahl);
            LP.push_back(hknoten);
            //cout << line << " " << zahl << endl;
        }
        addLineToKFG(LP);
    }
}

void KFGListC::addLineToKFG(KFGProgListC & LP) {
    int dummy = 0;
    char help[256];
    KFGListC::iterator KFG1 = end();
    KFGProgListC::iterator PROG1 = LP.end();
    //KFG1--;
    while (KFG1 != begin()) {
        KFG1--;
        if ((KFG1->getKFGNodeType() == EL) || (KFG1->getKFGNodeType() ==
ETH) || (KFG1->getKFGNodeType() == BE1) || (KFG1->getKFGNodeType() == BE1)) {
            KFG1--;
        }
        while ((PROG1 != LP.begin()) && (dummy != 1)) {
            if (KFG1->getLineNr() == PROG1->getLineNumber()) {
                strcpy(help,PROG1->getName());
                KFG1->setCodeLine(help);
                PROG1--;
                dummy = 1;
            }
            else{
                PROG1--;
            }
        }
        PROG1 = LP.end();
        dummy = 0;
    }
}

int KFGListC::zaehleDeklarationen(KFGTokenListC & TL) {
    int zaehler = 0;
    KFGTokenListC::iterator TListI = TL.end();
    while (strcmp(TListI->getName(),"main") != 0) {
        if (TListI->getTokenNodeType() == TD) {
            zaehler++;
        }
        TListI--;
    }
    return zaehler;
}

//Function for outputting the KFGList to the screen and to a file "CFGList".
void KFGListC::ListeAusgeben() {
    ofstream Ziell("CFGList.cfg");
    ostream_iterator<KFGListNodeC> Pos(Ziell, "\n");
    ostream_iterator<KFGDefC> PosD(Ziell, "\n");
    ostream_iterator<KFGUseC> PosU(Ziell, "\n");
    ostream_iterator<KFGUseC> PosP(Ziell, "\n");
}

```

```

KFGListC::iterator KLI = begin();
KFGDefListC::iterator DEF;
KFGUseListC::iterator USE;
KFGP_UseListC::iterator P_USE;
5 Ziell << "START" << endl << endl;
while (KLI != end()) {
    Ziell << "Line " << KLI->getLineNr() << endl;
    Ziell << "Zeile " << KLI->getCodeLine() << endl;
    Ziell << "Knoten " << KLI->getKnotenNummer() << endl;
10 Ziell << "KnotenTyp " << KLI->getKnotenIdent() << endl;
    Ziell << KLI->getStatement() << " " << KLI->getLevel() << endl;
    /*Pos++ = *KLI;
    DEF = KLI->Defs.begin();
    USE = KLI->Uses.begin();
15 P_USE = KLI->P_Uses.begin();
    while (DEF != KLI->Defs.end()) {
        /*PosD++ = *DEF;
        Ziell << "DEF: " << DEF->getDef() << " " <<
20 DEF->getScopeLevelD() << endl;
        DEF++;
    }
    while (USE != KLI->Uses.end()) {
        /*PosU++ = *USE;
        Ziell << "USE: " << USE->getUse() << " " <<
25 USE->getScopeLevelU() << endl;
        USE++;
    }
    while (P_USE != KLI->P_Uses.end()) {
        /*PosP++ = *P_USE;
        Ziell << "P_USE: " << P_USE->getUse() << "
30 " << P_USE->getScopeLevelU() << endl;
        P_USE++;
    }
    Ziell << endl;
    KLI++;
35 }
    Ziell << "STOP" << endl << endl;
    Ziell << "BASIC VARIABLES:" << endl;
    Ziell << "Number of empty branches: " << "0" << endl;
40 Ziell << "Number of decisions: " << Entscheidungen << endl;
    Ziell << "Number of instructions: " << Anweisungen << endl;
    Ziell << "Number of atomic predicates: " << Entscheidungen << endl;
    Ziell << "Number of predicates: " << Entscheidungen << endl;
    Ziell << "Number of atomic predicates which are arithm. relations: " << "0"
45 << endl;
    Ziell << "Number of loop decisions: " << Schleifenentscheidungen << endl;
    Ziell << "Number of non-interleaved loop decisions: " << "0" << endl;
    Ziell << "Number of count loop decisions: " << Zaehlschleifenentscheidungen
<< endl;
50 Ziell << "Number of declarations of structured data types: " << "0" <<
endl;
    Ziell << "Number of declarations: " << Anzahl_Deklarationen << endl;
    Ziell << "Number of real element declarations: " << "0" << endl;
    Ziell << "Number of basic type declarations: " << Anzahl_Deklarationen <<
55 endl;
    Ziell << "Number of Defs: " << Anzahl_Defs << endl;
    Ziell << "Number of Uses: " << Anzahl_Uses << endl;
    Ziell << "Number of P-uses: " << Anzahl_P_Uses << endl << endl;
    basisgroessenInDatei();
60 }

void KFGListC::basisgroessenInDatei() {
    ofstream datei("Basisgroessen.bgd", ios::out);
    datei << "0" << endl;
65 datei << Entscheidungen << endl;
    datei << Anweisungen << endl;
    datei << Entscheidungen << endl;
    datei << Entscheidungen << endl;
    datei << "0" << endl;
70 datei << Schleifenentscheidungen << endl;
    datei << "0" << endl;
    datei << Zaehlschleifenentscheidungen << endl;
    datei << "0" << endl;
    datei << Anzahl_Deklarationen << endl;
75 datei << "0" << endl;
    datei << Anzahl_Deklarationen << endl;
}

```

Variable	Mean	SD	Min	Max
Age	34.5	10.2	22	55
Gender	0.5	0.5	0	1
Marital status	0.6	0.5	0	1
Education	12.5	1.5	9	16
Income	1500	500	500	3000
Health status	0.7	0.4	0	1
Smoking status	0.3	0.5	0	1
Alcohol consumption	0.2	0.4	0	1
Exercise frequency	0.4	0.5	0	1
Stress level	0.6	0.5	0	1
Sleep quality	0.5	0.5	0	1
Work satisfaction	0.4	0.5	0	1
Life satisfaction	0.5	0.5	0	1
Depression score	10.5	5.0	0	30
Anxiety score	12.0	6.0	0	30
Quality of life score	75.0	10.0	50	100


```
datei << "0" << endl;  
datei << Anzahl_Defs << endl;  
datei << Anzahl_Uses << endl;  
datei << Anzahl_P_Uses << endl;
```

5

FILE: 00000000

```

    datei << "0" << endl;
    datei << "0" << endl;
    datei << "0" << endl;
    datei << "0" << endl;
5    datei << "0" << endl;
    datei << "0" << endl;
    datei << "0" << endl;
    datei << "0" << endl;
10   }

15

20

    #include "KFGListe.h"

25

    KFGListeT KFGListe;

30

    void KFGListeAusgeben(KFGListeT & L) {

        KFGListeT::iterator I = L.begin();

35        while(I != L.end())
            cout << *I++ << ' ';
            cout << " size() = " << L.size() << endl;
    }

40

    #include "KFGListNode.h"

    #include <iostream>

45

    ostream& operator << ( ostream& os, const KFGListNodeC& Node){

        os << endl << "KnotenNr:" << Node.KnotenNr << " Typ:" <<
        Node.KnotenIdent << endl << Node.Statement << " Level:" << Node.Level;
50        return os;
    }

    int KFGListNodeC::DummyNodeNr=1;

55

60

    #include "KFGNode.h"

    #include <iostream>

65

    ostream& operator << ( ostream& os, const KFGNodeC& Node){

        os << Node.Name << " " << Node.ScopeLevel;
        return os;
    }

70

    #include "KFGTokenList.h"

75

```

```

void KFGTokenListC::KFGListeAusgeben() {
    ofstream Ziel("CFGTokenList");
5    ostream_iterator<KFGTokenNodeC> oPos(Ziel, "\n");

    KFGTokenListC::iterator I = begin();

10    while(I != end()) {
        // *oPos++ = I->getName();
        *oPos++ = *I;
        // cout << I->getName() << " " << I->getScopeLevel() << " "
        << I->getTokenNodeType() << endl;
        I++;
15    }
    cout << " size() = " << size() << endl;
}

20

25 #include "KFGTokenNode.h"
#include <iostream>

    ostream& operator << ( ostream& os, const KFGTokenNodeC& Node){
        os << Node.Name << " " << Node.ScopeLevel << " " <<
30 Node.TokenNodeType << " " << Node.LineNumber << endl;
        return os;
    }

35 #include "KFGUse.h"
#include <iostream>

    ostream& operator << ( ostream& os, const KFGUseC& Node){
40     os << "USE: " << Node.Use << " " << Node.ScopeLevelU;
        return os;
    }

45 /*
    * Main program to test C++ grammar and preprocessor
    */

50

#include "JLStr.h"

55 #include "tokens.h"

#include "DLGLexer.h"
#include "BufferedCPreParser.h"
#include "CPreToCPPBuffer.h"
60 #include "JLTokenBuffer.h"
#include "CPPParserSym.h"
#include "KFGTokenList.h"
#include "KFGList.h"
#include "graph.h"
65 #include "AS_Slice.h"
#include "uwggraph.h"
#include "KFGProgList.h"
#include <iostream>

70 static void usage(char* progname);

int main(int argc, char *argv[])
{
    // For reporting memory usage
75     char *p = new char[100000];
    long heap1 = (long)(void*)p;

```



```

        if (inputFile != stdin)
        {
            // already have one
            usage(progname);
5         }
        FILE *fp = fopen(*argv, "r");
        if (fp == NULL)
        {
            fprintf(stderr, "%s: cannot open %s for input\n", progname, *argv);
10         exit(0);
        }
        inputFile = fp;
    }
    argc--;
15    argv++;
}

//printf("%s\n%s\n%s\n",includePath,definitions,inputFile);

20    // Create input stream, lexer
    DLGFileInput input(inputFile);
    DLGLexer scanner(&input);
    FastToken tok;
    scanner.setToken(&tok);

25    // Create preprocessor parser. Note that the preprocessor parser has
    // a built-in token buffer in the form of an input stack.
    BufferedCPreParser preprocessor(&scanner);
    preprocessor.init();

30    // set include path and defines directly for debugging
    if (includePath.length() == 0)
    {
        includePath = "c:\\devstudio\\vc\\include;\\msdev\\devstudio\\vc\\mfc
35    \\include";
    }
    if (definitions.length() == 0)
    {
        definitions =
40         " __cplusplus;"
        " __DATE__ = \"date\";"
        " __FILE__ = \"filename\";"
        " __LINE__ = 1;"
        " __TIME__ = \"time\";"
45         " __TIMESTAMP__ = \"timestamp\";"
        " _M_IX86=400;"
        " _MSC_VER=1100;"
        " _WIN32;"
        " _INTEGRAL_MAX_BITS=64";
50     }

    // Set preprocessor options
    preprocessor.SetIncludePath(includePath);
    preprocessor.SetDefinitions(definitions);

55    // Set options in parser to make it act standard with MS Extensions
    preprocessor.SetOption(CPreParserImp::OptMSExtensions, true);
    preprocessor.SetOption(CPreParserImp::OptBool, true);
    preprocessor.SetOption(CPreParserImp::OptWCharT, true);
    preprocessor.SetOption(CPreParserImp::OptPragmas, true);
60    preprocessor.SetOption(CPreParserImp::OptExpandPragmas, true);
    preprocessor.SetOption(CPreParserImp::OptTrackInclude, doTraceInclude);

    // Buffer to store tokens output by preprocessor
65    CPreToCPPBuffer pipe2(&preprocessor);

    // Connect preprocessor to second token buffer so that the
    // preprocessor can unilaterally squirt new tokens into the buffer
    preprocessor.SetBuffer(&pipe2);

70    // Token buffer for the usual backtracking, etc.
    JLTTokenBuffer pipe3(&pipe2, CPPParserSym::ConstLLK);

    // Create the C++ parser
75    CPPParserSym parser(&pipe3);

```

```
// Set parser options to look like MSVC++
parser.SetOption(CPPParserSym::OptPragmaMSPacking, true);
parser.SetOption(CPPParserSym::OptMSTypedefHack, true);
```

Parameter	Value	Unit
Initial concentration	100	mg/L
Initial pH	7.0	
Temperature	25	°C
Time	0, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912, 1073741824, 2147483648, 4294967296, 8589934592, 17179869184, 34359738368, 68719476736, 137438953472, 274877906944, 549755813888, 1099511627776, 2199023255552, 4398046511104, 8796093022208, 17592186044416, 35184372088832, 70368744177664, 140737488355328, 281474976710656, 562949953421312, 1125899906842624, 2251799813685248, 4503599627370496, 9007199254740992, 18014398509481984, 36028797018963968, 72057594037927936, 144115188075855872, 288230376151711744, 576460752303423488, 1152921504606846976, 2305843009213693952, 4611686018427387904, 9223372036854775808, 18446744073709551616, 36893488147419103232, 73786976294838206464, 147573952589676412928, 295147905179352825856, 590295810358705651712, 1180591620717411303424, 2361183241434822606848, 4722366482869645213696, 9444732965739290427392, 18889465931478580854784, 37778931862957161709568, 75557863725914323419136, 151115727451828646838272, 302231454903657293676544, 604462909807314587353088, 1208925819614629174706176, 2417851639229258349412352, 4835703278458516698824704, 9671406556917033397649408, 19342813113834066795298816, 38685626227668133590597632, 77371252455336267181195264, 154742504910672534362390528, 309485009821345068724781056, 618970019642690137449562112, 1237940039285380274899124224, 2475880078570760549798248448, 4951760157141521099596496896, 9903520314283042199192993792, 19807040628566084398385987584, 39614081257132168796771975168, 79228162514264337593543950336, 158456325028528675187087900672, 316912650057057350374175801344, 633825300114114700748351602688, 1267650600228229401496703205376, 2535301200456458802993406410752, 5070602400912917605986812821504, 10141204801825835211973625643008, 20282409603651670423947251286016, 40564819207303340847894502572032, 81129638414606681695789005144064, 162259276829213363391578010288128, 324518553658426726783156020576256, 649037107316853453566312041152512, 1298074214633706907132624082305024, 2596148429267413814265248164610048, 5192296858534827628530496329220096, 10384593717069655257060992658440192, 20769187434139310514121985316880384, 41538374868278621028243970633760768, 83076749736557242056487941267521536, 166153499473114484112975882535043072, 332306998946228968225951765070086144, 664613997892457936451903530140172288, 1329227995784915872903807060280344576, 2658455991569831745807614120560689152, 5316911983139663491615228241121378304, 10633823966279326983230456482242756608, 21267647932558653966460912964485513216, 42535295865117307932921825928971026432, 85070591730234615865843651857942052864, 170141183460469231731687303715884105728, 340282366920938463463374607431768211456, 680564733841876926926749214863536422912, 1361129467683753853853498429727072845824, 2722258935367507707706996859454145691648, 5444517870735015415413993718908291383296, 10889035741470030830827987437816582766592, 21778071482940061661655974875633165533184, 43556142965880123323311949751266331066368, 87112285931760246646623899502532662132736, 174224571863520493293247799005065324265472, 348449143727040986586495598010130648530944, 696898287454081973172991196020261297061888, 1393796574908163946345982392040522594123776, 2787593149816327892691964784081045188247552, 5575186299632655785383929568162090376495104, 11150372599265311570767859136324180752990208, 22300745198530623141535718272648361505980416, 44601490397061246283071436545296723011960832, 89202980794122492566142873090593446023921664, 178405961588244985132285746181186892047843328, 356811923176489970264571492362373784095686656, 713623846352979940529142984724747568191373312, 1427247692705959881058285969449495136382746624, 2854495385411919762116571938898990272765493248, 5708990770823839524233143877797980545530986496, 11417981541647679048466287755595961091061972992, 2283596308329	

```

    //preprocessor.doTrace(doTraceParse);
    parser.doTrace(doTraceParse);

    // Process top-level rule
5    parser.init();

    KFGTokenListC L1;
    parser.translation_unit(L1);

10    // Close the input file stream
    if (inputFile != stdin)
    {
        fclose(inputFile);
    }

15    // For reporting memory usage
    // For reporting memory usage
    p = new char[100000];
    long heap2 = (long)(void*)p;
20    delete [] p;
    cout << "Approx heap usage before dump: " << (heap2 - heap1) << endl;

    if (doDump)
    {
25        // Dump the scope hierarchy
        cout << "Dump of scope hierarchy" << endl;
        parser.DumpScopes();
        cout << endl;
    }

30    // For reporting memory usage
    // For reporting memory usage
    p = new char[100000];
    long heap3 = (long)(void*)p;
35    delete [] p;
    cout << "Approx heap usage after dump: " << (heap3 - heap1) << endl;
    L1.KFGListeAusgeben();
    //L1.KFGTokenListToKFGList();

40    KFGListC L2;
    //KFGListC::iterator Iter;
    L2.TokenList2KFGList(L1);
    L2.ListeAusgeben();

45    SliceC Slice;
    Slice.startBuildSlice(L2);
    //Slice.buildTestGraph(L2);
    //cout << Slice;

50    uwggraphC uwggraph;
    //uwggraph.buildIfTree(Slice);
    uwggraph.startBuildFT(Slice);
    cout << uwggraph;

55    return 0;
}

static void usage(char* progname)
{
60    fprintf(
        stderr,
        "usage: %s [-I directories] [-D definitions] [-traceParse] [ -traceInclude ]
        [-o ofile] [ifile]\n"
        "    -I directories: semicolon-separated list of include directories\n"
65        "    -D definitions: semicolon-separated list of definitions, like:\n"
        "        symbol1;symbol2=value2\n"
        "    -traceParse: output debugging information\n"
        "    -traceInclude: output trace of include stack\n"
        "    -dump: dump type and scope hierarchy\n"
70        "    ifile: name of input file (otherwise it uses stdin)\n",
        progname
    );
    exit(1);
}

75    #include <iostream>

```



```

#include <iterator>
#include <algorithm>
#include <fstream>
#include "uwggraph.h"

5 using namespace std;

SliceC::iterator uwggraphC::findOutputNode(SliceC & S1) {
    int dummy = 0;
    SliceC::iterator SL1 = S1.begin();
    SliceC::iterator HELP = S1.begin();
    while ((SL1 != S1.end()) && (dummy != 1)) {
        if ( (*SL1).first.getKFGNodeType() == OP ) {
            HELP = SL1;
            dummy = 1;
        }
        SL1 ++;
    }
    return HELP;
20 }

void uwggraphC::startBuildFT(SliceC & S1) {
    int pos1 = 0;
    int Pos1 = 0;
    int SliceNr = 0;
    int LineNr = 0;
    int inLoop = 0;
    SliceAusgeben(S1);
    char NodeText[128];
    char Bemerkung[1000];
    SliceC::iterator SL1 = findOutputNode(S1);
    SliceNr = (*SL1).first.getKnotenNummer();
    LineNr = (*SL1).first.getLineNr();
    sprintf(NodeText, "Op%d", SliceNr);
    strcpy(Bemerkung, SL1->first.getCodeLine());
    //sprintf(Bemerkung, "Line %d", LineNr);
    SliceC::Nachfolger::iterator BEGIN = (*SL1).second.begin();
    SliceC::Nachfolger::iterator END = (*SL1).second.end();
    while (BEGIN != END) {
        if (BEGIN->second == KFK) {
            uwgknotenC hknoten1(EFFECT, SliceNr, NodeText, Bemerkung);
            Pos1 = insert(hknoten1);
            SliceC::iterator SLPUSE = findLastPUse(S1, SliceNr);
            checkLoopOrCond(S1, SLPUSE, SL1, Pos1);
            inLoop = 1;
            BEGIN++;
        }
        else {
            BEGIN++;
        }
    }
    if (inLoop == 0) {
        uwgknotenC hknoten1(EFFECT, SliceNr, NodeText, Bemerkung);
        uwgknotenC hknoten2(OR, "OR");
        insert(hknoten1, hknoten2, 0);
        pos1 = size()-1;
        uwgknotenC hknoten3(CAUSE, SliceNr, NodeText, Bemerkung);
        insert(hknoten2, hknoten3, 0);
        addFirstNodesToFT(S1, SliceNr, pos1);
    }
    check();
}

65 void uwggraphC::checkLoopOrCond(SliceC & S1, SliceC::iterator SLPUSE,
SliceC::iterator SLORIG, int Pos1) {
    int PosRet = 0;
    switch (SLPUSE->first.getKFGNodeType()) {
        case IFC:
            PosRet = buildInIfTree(S1, SLPUSE, SLORIG, Pos1);
            //cout << "Test1a: " << SLHELP->first.getKnotenNummer() << endl;
            break;
        case LC:
            buildInLoopTree(S1, Pos1, SLPUSE, SLORIG);
            //cout << "Test1b: " << SLHELP->first.getKnotenNummer() << endl;
75
    }
}

```

TUEDEC 5 24 09 50

```

        break;
    default:
        cout << "Ups" << endl;
    }
5   }

void uwggraphC::addFirstNodesToFT(SliceC & S1, int KnotenNr, int Pos1) {
    int helpNr = 0;
    int ret = 0;
    int pos = 0;
    int KnotenNr1 = 0;
    int LineNr1 = 0;
    char NodeText[128];
    char Bemerkung[1000];
15   SliceC::iterator NODE = defineIterator(S1, KnotenNr);
    SliceC::Nachfolger::iterator BEGIN = NODE->second.begin();
    SliceC::Nachfolger::iterator END = NODE->second.end();
    while (BEGIN != END) {
20       helpNr = BEGIN->first;
        KnotenNr1 = S1[helpNr].first.getKnotenNummer();
        SliceC::iterator NODE1 = defineIterator(S1, KnotenNr1);
        if (NODE1->first.getLevel() > 1) {
            SliceC::iterator PUSE = findLastPUse(S1, KnotenNr1);
25           switch (PUSE->first.getKFGNodeType()) {
                case IFC:
                    ret = buildInIfTree(S1, PUSE, NODE1, Pos1);
                    break;
                case LC:
30                     buildInLoopTree(S1, Pos1, PUSE, NODE1);
                    break;
                default:
                    cout << "Something is wrong!" << endl;
            }
35         }
        else {
            LineNr1 = S1[helpNr].first.getLineNr();
            sprintf(NodeText, "Op%d", KnotenNr1);
            //sprintf(Bemerkung, "Line %d", LineNr1);
40             strcpy(Bemerkung, S1[helpNr].first.getCodeLine());
            uwgknotenC hknoten1(CAUSE, KnotenNr1, NodeText, Bemerkung);
            pos = insert(hknoten1);
            verbindeEcken(Pos1, pos, 0);
            addFirstNodesToFT(S1, KnotenNr1, Pos1);
45         }
        BEGIN++;
    }
}

50 SliceC::iterator uwggraphC::findLastPUse(SliceC & S1, int SliceNr) {
    int helpNr1 = 0;
    int SliceNr1 = 0;
    SliceC::iterator SL1 = defineIterator(S1, SliceNr);
55   SliceC::iterator SLHELP = SL1;
    SliceC::Nachfolger::iterator BEGIN = (*SL1).second.begin();
    SliceC::Nachfolger::iterator END = (*SL1).second.end();
    while (BEGIN != END) {
        if (BEGIN->second == KFK) {
60             helpNr1 = BEGIN->first;
            SliceNr1 = S1[helpNr1].first.getKnotenNummer();
            SLHELP = defineIterator(S1, SliceNr1);
            SLHELP = findLastPUse(S1, SliceNr1);
        }
65         BEGIN++;
    }
    return SLHELP;
}

70 SliceC::iterator uwggraphC::findLastPUse2(SliceC & S1, int SliceNr, int RefNr) {
    int helpNr1 = 0;
    int SliceNr1 = 0;
    SliceC::iterator SLRETURN = defineIterator(S1, SliceNr);
    SliceC::iterator SLHELP = SLRETURN;
75   SliceC::Nachfolger::iterator BEGIN = SLRETURN->second.begin();
    SliceC::Nachfolger::iterator END = SLRETURN->second.end();
    while (BEGIN != END) {

```

TUEOCT 540850

```

        if(BEGIN->second == KFK) {
            helpNr1 = BEGIN->first;
            SliceNr1 = S1[helpNr1].first.getKnotenNummer();
            SLHELP = defineIterator(S1, SliceNr1);
5            SLHELP = findLastPUse2(S1, SliceNr1, RefNr);
            if (SLHELP->first.getKnotenNummer() != RefNr) {
                SLRETURN = SLHELP;
            }
        }
10        BEGIN++;
    }
    return SLRETURN;
}

15
SliceC::iterator uwggraphC::lookForNextPUse(SliceC & S1, SliceC::iterator SNODE,
SliceC::iterator SLPUSE) {
    int helpNr1 = 0;
20    int helpNr2 = 0;
    int helpNr3 = 0;
    int dummy = 0;
    int dummy1 = 0;
    int KnotenNr1 = 0;
25    int KnotenNr2 = 0;
    int RefNr = SLPUSE->first.getKnotenNummer();
    SliceC::iterator HELP = SNODE;
    SliceC::iterator RETURN = SNODE;
    SliceC::Nachfolger::iterator BEGIN1 = SNODE->second.begin();
30    SliceC::Nachfolger::iterator END1 = SNODE->second.end();
    while ((BEGIN1 != END1) && (dummy != 1)) {
        helpNr1 = BEGIN1->first;
        SliceC::Nachfolger::iterator BEGIN2 = S1[helpNr1].second.begin();
        SliceC::Nachfolger::iterator END2 = S1[helpNr1].second.end();
35        while ((BEGIN2 != END2) && (dummy1 != 1)) {
            if (BEGIN2->second == KFK) {
                helpNr2 = BEGIN2->first;
                if (S1[helpNr2].first.getKnotenNummer() != RefNr) {
40                    KnotenNr1 = S1[helpNr2].first.getKnotenNummer();
                    RETURN = defineIterator(S1, KnotenNr1);
                    SliceC::Nachfolger::iterator BEGIN3 = RETURN-
>second.begin();
                    SliceC::Nachfolger::iterator END3 = RETURN-
>second.end();
45                    while (BEGIN3 != END3) {
                        if (BEGIN3->second == KFK) {
                            helpNr3 = BEGIN3->first;
                            if
50                            (S1[helpNr3].first.getKnotenNummer() != RefNr) {
                                KnotenNr2 = S1[helpNr3]
                                .first.getKnotenNummer();
                                RETURN = findLastPUse2
                                (S1, KnotenNr2, RefNr);
                                }
                            }
55                            BEGIN3++;
                        }
                    }
                    dummy1 = 1;
                    dummy = 1;
60                }
            }
            else {
                KnotenNr1 = S1[helpNr1].first.getKnotenNummer();
                HELP = defineIterator(S1, KnotenNr1);
                RETURN = lookForNextPUse(S1, HELP, SLPUSE);
65            }
        }
        BEGIN2++;
    }
    BEGIN1++;
70    return RETURN;
}

SliceC::iterator uwggraphC::returnCondNode(SliceC & S1, int SliceNr) {
75    int helpNr = 0;

```

```

    int dummy = 0;
    int dummy2 = 0;
    int SliceNr2 = 0;
    SliceC::iterator SL1 = defineIterator(S1, SliceNr);
5   SliceC::iterator HELP = SL1;
    SliceC::Nachfolger::iterator BEGIN = (*SL1).second.begin();
    SliceC::Nachfolger::iterator END = (*SL1).second.end();
    while ((BEGIN != END) && (dummy != 1)) {
        helpNr = BEGIN->first;
10   SliceNr = S1[helpNr].first.getKnotenNummer();
        HELP = defineIterator(S1, SliceNr);
        SliceC::Nachfolger::iterator BEGIN2 = (*HELP).second.begin();
        SliceC::Nachfolger::iterator END2 = (*HELP).second.end();
        while ((BEGIN2 != END2) && (dummy2 != 1)) {
15             if ((*BEGIN2).second == KFK) {
                helpNr = (*BEGIN2).first;
                SliceNr2 = S1[helpNr].first.getKnotenNummer();
                HELP = defineIterator(S1, SliceNr2);
                dummy2 = 1;
20             }
            BEGIN2++;
        }
        BEGIN++;
25    }
    return HELP;
}

//Function investigates whether or not two control structures are interleaved.
30 int uwggraphC::checkPUses1(SliceC & S1, SliceC::iterator SLPUSEREF,
    SliceC::iterator SLPUSE) {
    int helpreturn = 0;
    int KnotenNummerRef = 0;
    int helpNr1 = 0;
35    int KnotenNr1 = 0;
    KnotenNummerRef = SLPUSE->first.getKnotenNummer();
    SliceC::Nachfolger::iterator BEGIN1 = SLPUSEREF->second.begin();
    SliceC::Nachfolger::iterator END1 = SLPUSEREF->second.end();
    while (BEGIN1 != END1) {
40        if (BEGIN1->second == KFK) {
            helpNr1 = BEGIN1->first;
            KnotenNr1 = S1[helpNr1].first.getKnotenNummer();
            if (KnotenNr1 == KnotenNummerRef) {
                helpreturn = 1;
45            }
        }
        else {
            SLPUSEREF = defineIterator(S1, KnotenNr1);
            helpreturn = checkPUses1(S1, SLPUSEREF, SLPUSE);
50        }
        BEGIN1++;
    }
    return helpreturn;
55 }

int uwggraphC::checkPUses2(SliceC & S1, SliceC::iterator SLPUSEREF,
    SliceC::iterator SLPUSE) {
    int helpreturn = 0;
60    int KnotenNummerRef = 0;
    int helpNr1 = 0;
    int KnotenNr1 = 0;
    KnotenNummerRef = SLPUSEREF->first.getKnotenNummer();
    SliceC::Nachfolger::iterator BEGIN1 = SLPUSE->second.begin();
65    SliceC::Nachfolger::iterator END1 = SLPUSE->second.end();
    while (BEGIN1 != END1) {
        if (BEGIN1->second == KFK) {
            helpNr1 = BEGIN1->first;
            KnotenNr1 = S1[helpNr1].first.getKnotenNummer();
70            if (KnotenNr1 == KnotenNummerRef) {
                helpreturn = 1;
            }
        }
        else {
            SLPUSE = defineIterator(S1, KnotenNr1);
75            helpreturn = checkPUses2(S1, SLPUSEREF, SLPUSE);
        }
    }
}

```

```

    BEGIN1++;
}
return helpreturn;
}

int uwggraphC::buildInIfTree(SliceC & S1, SliceC::iterator SLIF, SliceC::iterator
SLORIG, int pos1) {
    int pos2 = 0;
    int posIFOR = 0;
    int posIFDFOR = 0;
    int posIFKFOR = 0;
    int posIFDFORA2 = 0;
    char NodeText[128];
    char Bemerkung[1000];
    int KnotenNr = SLIF->first.getKnotenNummer();
    int LineNr = SLIF->first.getLineNr();
    sprintf(Bemerkung, "Verzweigung(%d)", LineNr);
    strcpy(NodeText, SLIF->first.getCodeLine());
    uwgknotenC hknoten1(OR, NodeText, Bemerkung);
    pos2 = insert(hknoten1);
    posIFOR = size() - 1;
    verbindeEcken(pos1, pos2, 0);
    sprintf(NodeText, "Verzweigung_KF(%d)", LineNr);
    uwgknotenC hknoten5(OR, NodeText);
    posIFKFOR = insert(hknoten5);
    verbindeEcken(pos2, posIFKFOR, 0);
    build_IPKF_Part(S1, posIFKFOR, SLIF);
    switch (SLORIG->first.getKnotenIdent()) {
    case THEN:
        {
            sprintf(NodeText, "Verzweigung_DF_Alt.1(%d)", LineNr);
            uwgknotenC hknoten2(AND, NodeText);
            insert(hknoten1, hknoten2, 0);
            sprintf(Bemerkung, "Alt.1(%d)", LineNr);
            sprintf(NodeText, "Alt.1(%d)", LineNr);
            uwgknotenC hknoten3(CAUSE, NodeText, Bemerkung);
            insert(hknoten2, hknoten3, 0);
            sprintf(NodeText, "Alt.1(%d)", LineNr);
            uwgknotenC hknoten4(OR, NodeText);
            insert(hknoten2, hknoten4, 0);
            posIFDFOR = size() - 1;
            build_A1_Part(S1, posIFDFOR, SLIF, SLORIG);
        }
        break;
    case ELSE:
        {
            sprintf(NodeText, "Verzweigung_DF_Alt.2(%d)", LineNr);
            uwgknotenC hknoten2(AND, NodeText);
            insert(hknoten1, hknoten2, 0);
            sprintf(Bemerkung, "Alt.2(%d)", LineNr);
            sprintf(NodeText, "Alt.2(%d)", LineNr);
            uwgknotenC hknoten3(CAUSE, NodeText, Bemerkung);
            insert(hknoten2, hknoten3, 0);
            sprintf(NodeText, "Alt.2(%d)", LineNr);
            uwgknotenC hknoten4(OR, NodeText);
            insert(hknoten2, hknoten4, 0);
            posIFDFORA2 = size() - 1;
            build_A1_Part(S1, posIFDFORA2, SLIF, SLORIG);
        }
        break;
    default:
        cout << "Ouch!!!" << endl;
    }
    return posIFDFOR;
}

void uwggraphC::build_A1_Part(SliceC & S1, int posIFDFOR, SliceC::iterator SLIF,
SliceC::iterator SLNODE) {
    int pos0 = 0;
    int pos1 = 0;
    int ret = 0;
    int dummy = 0;
    int checkNr = 1;

```

```

int checkPUse = 1;
int helpNr1 = 0;
int helpNr2 = 0;
int KnotenNr0 = 0;
int KnotenNr1 = 0;
int KnotenNr2 = 0;
int LineNr0 = 0;
int LineNr1 = 0;
char NodeText0[128];
char Bemerkung0[1000];
KnotenNr0 = SLNODE->first.getKnotenNumber();
LineNr0 = SLNODE->first.getLineNr();
sprintf(NodeText0, "Op%d", KnotenNr0);
//sprintf(Bemerkung0, "Line %d", LineNr0);
strcpy(Bemerkung0, SLNODE->first.getCodeLine());
uwgknotenC hknoten0(CAUSE, KnotenNr0, NodeText0, Bemerkung0);
pos0 = insert(hknoten0);
verbindeEcken(posIFDFOR, pos0, 0);
SliceC::Nachfolger::iterator BEGIN0 = SLNODE->second.begin();
SliceC::Nachfolger::iterator END0 = SLNODE->second.end();
while (BEGIN0 != END0) {
    if (BEGIN0->second == DFK) {
        helpNr1 = BEGIN0->first;
        KnotenNr1 = S1[helpNr1].first.getKnotenNumber();
        SLNODE = defineIterator(S1, KnotenNr1);
        if (KnotenNr1 < KnotenNr0) {
            SliceC::Nachfolger::iterator BEGIN1 = SLNODE->second.begin();
            SliceC::Nachfolger::iterator END1 = SLNODE->second.end();
            while (BEGIN1 != END1) {
                if (BEGIN1->second == KFK) {
                    helpNr2 = BEGIN1->first;
                    KnotenNr2 = S1[helpNr2].first.getKnotenNumber();
                    defineIterator(S1, KnotenNr2);
                    checkNr = checkUWGNode(KnotenNr2);
                    if (SLIF->first.getKnotenNumber() > KnotenNr2) {
                        checkPUse = 0;
                    } else {
                        checkPUse = 1;
                    }
                    if (KnotenNr2 != SLIF->first.getKnotenNumber()) {
                        if (checkPUse == 0) {
                            dummy = 1;
                            HELPPUSE = findOutmostPUse(S1, HELPPUSE);
                            switch (HELPPUSE->first.getKFGNodeType()) {
                                case LC:
                                    buildInLoopTree(S1, posIFDFOR, HELPPUSE, SLNODE);
                                    break;
                                case IFC:
                                    ret = buildInIfTree(S1, HELPPUSE, SLNODE, posIFDFOR);
                                    break;
                                default:
                                    cout << "Incorrect path in A1! " << endl;
                            }
                        } else {
                            if (checkNr == 0) {
                                dummy = 1;
                                HELPPUSE = findOutmostPUse(S1, HELPPUSE);
                                switch (HELPPUSE->first.getKFGNodeType()) {

```



```
checkNr = checkUWGNode(KnotenNr2);  
if (SLPUSE->first.getKnotenNummer() >  
KnotenNr2) {  
5  checkPUses1(S1,SLPUSE,HELPPUSE);  
    checkPUse =  
    }  
}
```

TUE OCT 23 09:05:50


```

    int KnotenNr = 0;
    int LineNr = 0;
    KnotenNr = SLPUSE->first.getKnotenNummer();
    LineNr = SLPUSE->first.getLineNr();
5   char NodeText[128];
    char Bemerkung[1000];
    sprintf(Bemerkung, "Schleife(%d)", KnotenNr);
    strcpy(NodeText, SLPUSE->first.getCodeLine());
    uwgknotenC hknoten1(OR, NodeText, Bemerkung);
10   pos1 = insert(hknoten1);
    verbindeEcken(Pos1, pos1, 0);
    sprintf(NodeText, "Schleife_DF_Durchl.1(%d)", LineNr);
    uwgknotenC hknoten2(AND, NodeText);
    sprintf(NodeText, "Schleife_DF_Durchl.+(%d)", LineNr);
15   uwgknotenC hknoten3(AND, NodeText);
    pos3 = insert(hknoten3);
    verbindeEcken(pos1, pos3, 0);
    sprintf(NodeText, "Schleife_KF(%d)", LineNr);
    uwgknotenC hknoten4(OR, NodeText);
20   insert(hknoten1, hknoten2, 0);
    insert(hknoten1, hknoten4, 0);
    posLOOP_KF = size() - 1;
    sprintf(Bemerkung, "Durchl.1(%d)", LineNr);
    sprintf(NodeText, "Durchl.1(%d)", LineNr);
25   uwgknotenC hknoten5(CAUSE, NodeText, Bemerkung);
    sprintf(NodeText, "Durchl.1(%d)", LineNr);
    uwgknotenC hknoten6(OR, NodeText);
    insert(hknoten2, hknoten5, 0);
    insert(hknoten2, hknoten6, 0);
30   posOR_D1 = size() - 1;
    sprintf(Bemerkung, "Durchl.+(%d)", LineNr);
    sprintf(NodeText, "Durchl.+(%d)", LineNr);
    uwgknotenC hknoten7(CAUSE, NodeText, Bemerkung);
    sprintf(NodeText, "Durchl.+(%d)", LineNr);
35   uwgknotenC hknoten8(OR, NodeText);
    insert(hknoten3, hknoten7, 0);
    posOR_D2 = insert(hknoten8);
    verbindeEcken(pos3, posOR_D2, 0);
    sprintf(NodeText, "KF(%d)", LineNr);
40   uwgknotenC hknoten9(AND, NodeText);
    insert(hknoten4, hknoten9, 0);
    insert(hknoten3, hknoten5, 0);
    posAND_KF = size() - 1;
    insert(hknoten9, hknoten5, 0);
45   NodeNrD2 = buildIn_LoopKF_ANDPart(S1, posAND_KF, SLPUSE);
    buildIn_LoopKF_ORPart(S1, posLOOP_KF, SLPUSE, NodeNrD2);
    //buildIn_D2_Part(S1, posOR_D2, SLPUSE, SLNODE, NodeNrD2);
    buildIn_D1_Part(S1, posOR_D1, SLPUSE, SLNODE, NodeNrD2);
    buildIn_D2_Part(S1, posOR_D2, SLPUSE, SLNODE, NodeNrD2);
50   }

void uwggraphC::buildIn_D1_Part(SliceC & S1, int posOR_D1, SliceC::iterator SLPUSE,
55   SliceC::iterator SLNODE, int D2_RefNr) {
    int pos1 = 0;
    int ret = 0;
    int KnotenNr1 = 0;
    int LineNr1 = 0;
60   SliceC::iterator ITER1 = find_D1_Node(S1, SLPUSE, SLNODE);
    SliceC::iterator HELP = ITER1;
    switch(ITER1->first.getKFGNodeType()) {
    case IFC:
        HELP = find_D1_Node(S1, ITER1, SLNODE);
        ret = buildInIfTree(S1, ITER1, HELP, posOR_D1);
65         break;
    case LC:
        HELP = find_D1_Node(S1, ITER1, SLNODE);
        buildInLoopTree(S1, posOR_D1, ITER1, SLNODE);
70         break;
    default:
        addAllD1Nodes(S1, ITER1, posOR_D1, D2_RefNr);
    }
75   }

```

```

SliceC::iterator uwggraphC::find_D1_Node(SliceC & S1, SliceC::iterator SLUSE,
SliceC::iterator SLNODE) {
    int helpNr1 = 0;
    int helpNr2 = 0;
5    int dummy1 = 0;
    int dummy2 = 0;
    int KnotenNrRet = 0;
    int KnotenNrRet1 = 0;
    int PUseNr = SLPUSE->first.getKnotenNummer();
    int PUseLevel = SLPUSE->first.getLevel();
10    SliceC::iterator RETURNITER = SLNODE;
    KnotenNrRet1 = SLNODE->first.getKnotenNummer();
    if (KnotenNrRet1 == (PUseNr + 1)) {
        RETURNITER = defineIterator(S1, KnotenNrRet1);
15        dummy1 = 1;
        dummy2 = 1;
    }
    SliceC::Nachfolger::iterator BEGIN1 = SLNODE->second.begin();
    SliceC::Nachfolger::iterator END1 = SLNODE->second.end();
20    while ((BEGIN1 != END1) && (dummy1 != 1)) {
        helpNr1 = BEGIN1->first;
        if ((S1[helpNr1].first.getKnotenNummer() > PUseNr) &&
(S1[helpNr1].first.getLevel() >= PUseLevel)) {
            if (S1[helpNr1].first.getLevel() > PUseLevel) {
25                KnotenNrRet1 = S1[helpNr1].first.getKnotenNummer();
                if (KnotenNrRet1 == (PUseNr + 1)) {
                    RETURNITER = defineIterator(S1, KnotenNrRet1);
                    dummy1 = 1;
                    dummy2 = 1;
                }
30                SliceC::Nachfolger::iterator BEGIN2 =
S1[helpNr1].second.begin();
                SliceC::Nachfolger::iterator END2 =
S1[helpNr1].second.end();
35                while ((BEGIN2 != END2) && (dummy2 != 1)) {
                    if (BEGIN2->second == KFK) {
                        helpNr2 = BEGIN2->first;
                        KnotenNrRet =
S1[helpNr2].first.getKnotenNummer();
40                        if (KnotenNrRet != PUseNr) {
                            RETURNITER =
defineIterator(S1, KnotenNrRet);
                            dummy1 = 1;
                            dummy2 = 1;
                        }
45                    }
                }
                BEGIN2++;
            }
        }
50        else {
            KnotenNrRet = S1[helpNr1].first.getKnotenNummer();
            RETURNITER = defineIterator(S1, KnotenNrRet);
            dummy1 = 1;
        }
55    }
    BEGIN1++;
}
if ((RETURNITER == SLNODE) && (dummy1 == 0)) {
    BEGIN1 = SLNODE->second.begin();
60    while (BEGIN1 != END1) {
        helpNr1 = BEGIN1->first;
        KnotenNrRet = S1[helpNr1].first.getKnotenNummer();
        SliceC::iterator SLNODE = defineIterator(S1, KnotenNrRet);
        RETURNITER = find_D1_Node(S1, SLPUSE, SLNODE);
65        BEGIN1++;
    }
}
return RETURNITER;
70 }

void uwggraphC::buildIn_D2_Part(SliceC & S1, int posOR_D2, SliceC::iterator SLPUSE,
SliceC::iterator SLNODE, int KnotenNrD2) {
    int pos1 = 0;
75    int pos2 = 0;
    int ret = 0;

```

```
int helpNr1 = 0;  
int helpNr2 = 0;
```

FOUO - 6840350

```

int KnotenNr1 = 0;
int LineNr1 = 0;
int KnotenNrD2Ret = 0;
int USEinD2KnotenNr = 0;
5 char Bemerkung1[1000];
char NodeText1[128];
SliceC::iterator D2_NODE = defineIterator(S1, KnotenNrD2);
KnotenNr1 = D2_NODE->first.getKnotenNummer();
LineNr1 = D2_NODE->first.getLineNr();
10 sprintf(NodeText1,"Op%d",KnotenNr1);
//sprintf(Bemerkung1,"Line %d",LineNr1);
strcpy(Bemerkung1,D2_NODE->first.getCodeLine());
uwgknotenC hknoten1(CAUSE,KnotenNr1,NodeText1,Bemerkung1);
pos1 = insert(hknoten1);
15 verbindeEcken(posOR_D2,pos1,0);
SliceC::Nachfolger::iterator BEGIN1 = D2_NODE->second.begin();
SliceC::Nachfolger::iterator END1 = D2_NODE->second.end();
while (BEGIN1 != END1) {
    if (BEGIN1->second == DFK) {
20         helpNr1 = BEGIN1->first;
        KnotenNr1 = S1[helpNr1].first.getKnotenNummer();
        LineNr1 = S1[helpNr1].first.getLineNr();
        sprintf(NodeText1,"Op%d",KnotenNr1);
        //sprintf(Bemerkung1,"Line %d",LineNr1);
25         strcpy(Bemerkung1,S1[helpNr1].first.getCodeLine());
        uwgknotenC hknoten2(CAUSE,KnotenNr1,NodeText1,Bemerkung1);
        pos2 = insert(hknoten2);
        verbindeEcken(posOR_D2,pos2,0);
        SliceC::Nachfolger::iterator BEGIN2 = S1[helpNr1].second.begin();
30         SliceC::Nachfolger::iterator END2 = S1[helpNr1].second.end();
        while (BEGIN2 != END2) {
            helpNr2 = BEGIN2->first;
            if ((BEGIN2->second == DFK) &&
(S1[helpNr2].first.getKnotenNummer() != KnotenNrD2)) {
35                 //SliceC::iterator SLNODE1 =
                defineIterator(S1,KnotenNr1);
                //buildin_D2_Part(S1,posOR,SLPUSE,SLNODE1,KnotenNrD2);
                BEGIN2++;
40             }
        }
        BEGIN1++;
    }
    SliceC::iterator USEinD2 = find_D1_Node(S1, SLPUSE, SLNODE);
45     SliceC::iterator HELP = USEinD2;
    if (USEinD2->first.getLevel() > SLPUSE->first.getLevel()) {
        USEinD2KnotenNr = USEinD2->first.getKnotenNummer();
        KnotenNrD2Ret = findD2Node(S1, USEinD2);
        if (KnotenNrD2Ret == USEinD2KnotenNr) {
50             switch(USEinD2->first.getKFGNodeType()) {
                case IFC:
                    HELP = find_D1_Node(S1,USEinD2,SLNODE);
                    //ret = buildInIfTree(S1,USEinD2,HELP,posOR);
                    ret = buildD2InIfTree(S1,USEinD2,HELP,posOR_D2);
55                     break;
                case LC:
                    HELP = find_D1_Node(S1,USEinD2,SLNODE);
                    buildinLoopTree(S1,posOR_D2,USEinD2,SLNODE);
                    break;
60                 default:
                    cout << "Oups!!!" << endl;
            }
        }
    }
65 }

int uwggraphC::findD2Node(SliceC & S1, SliceC::iterator PUSE) {
    int dummy = 0;
70     int helpNr1 = 0;
    int helpNr2 = 0;
    int KnotenNrReturn = PUSE->first.getKnotenNummer();
    int PUSEKnotenNr = PUSE->first.getKnotenNummer();
    SliceC::Nachfolger::iterator BEGIN1 = PUSE->second.begin();
75     SliceC::Nachfolger::iterator END1 = PUSE->second.end();
    while ((BEGIN1 != END1) && (dummy != 1)) {

```

```
if (BEGIN1->second == DFK) {  
    helpNr1 = BEGIN1->first;
```

FOUO 55403660

```

        SliceC::Nachfolger::iterator BEGIN2 =
S1[helpNr1].second.begin();
        SliceC::Nachfolger::iterator END2 =
S1[helpNr1].second.end();
5      while ((BEGIN2 != END2) && (dummy != 1)) {
          if (BEGIN2->second == KFK) {
              helpNr2 = BEGIN2->first;
              if (S1[helpNr2].first.getKnotenNummer() ==
10      PUSEKnotenNr) {
                  KnotenNrReturn =
S1[helpNr2].first.getKnotenNummer();
                  dummy = 1;
              }
          }
15      BEGIN2++;
      }
      BEGIN1++;
  }
20  return KnotenNrReturn;
}

int uwggraphC::buildIn_LoopKF_ANDPart(SliceC & S1, int posAND_KF, SliceC::iterator SLPUSE) {
25  int pos = 0;
  int helpNr1 = 0;
  int helpNr2 = 0;
  int RefPUse = 0;
  int KnotenNr = 0;
  int LineNr = 0;
30  int dummy = 0;
  int dummy1 = 0;
  char Bemerkung[1000];
  char NodeText[128];
  RefPUse = SLPUSE->first.getKnotenNummer();
35  SliceC::Nachfolger::iterator BEGIN = SLPUSE->second.begin();
  SliceC::Nachfolger::iterator END = SLPUSE->second.end();
  while ((BEGIN != END) && (dummy1 != 1)) {
      if (BEGIN->second == DFK) {
          helpNr1 = BEGIN->first;
40      SliceC::Nachfolger::iterator BEGIN2 = S1[helpNr1].second.begin();
          SliceC::Nachfolger::iterator END2 = S1[helpNr1].second.end();
          while ((BEGIN2 != END2) && (dummy != 1)) {
              if (BEGIN2->second == KFK) {
                  helpNr2 = BEGIN2->first;
45      if (S1[helpNr2].first.getKnotenNummer() == RefPUse) {
                      KnotenNr = S1[helpNr1].first.getKnotenNummer();
                      LineNr = S1[helpNr1].first.getLineNr();
                      sprintf(NodeText, "Op%d", KnotenNr);
                      //sprintf(Bemerkung, "Line %d", LineNr);
50      strcpy(Bemerkung, S1[helpNr1].first.getCodeLine());
                      uwgknotenC
hknoten(CAUSE, KnotenNr, NodeText, Bemerkung);
                      pos = insert(hknoten);
55      verbindeEcken(posAND_KF, pos, 0);
                      dummy = 1;
                      dummy1 = 1;
                  }
              }
60      BEGIN2++;
          }
      }
      BEGIN++;
  }
65  return KnotenNr;
}

void uwggraphC::buildIn_LoopKF_ORPart(SliceC & S1, int posLOOP_KF, SliceC::iterator
SL1, int KnotenNrD2) {
70  int pos1 = 0;
  int pos2 = 0;
  int helpNr1 = 0;
  int helpNr2 = 0;
  int KnotenNr = 0;
75  int KnotenNr1 = 0;
  int LineNr = 0;
  int LineNr1 = 0;

```



```

char NodeText[128];
char Bemerkung[1000];
KnotenNr = SL1->first.getKnotenNummer();
LineNr = SL1->first.getLineNr();
5   sprintf(NodeText,"Op%d",KnotenNr);
   //sprintf(Bemerkung,"Line %d",LineNr);
   strcpy(Bemerkung,SL1->first.getCodeLine());
   uwgknotenC hknoten1(CAUSE, KnotenNr, NodeText,Bemerkung);
   pos1 = insert(hknoten1);
10  verbindeEcken(posLOOP_KF,pos1,0);
   SliceC::Nachfolger::iterator BEGIN = SL1->second.begin();
   SliceC::Nachfolger::iterator END = SL1->second.end();
   while (BEGIN != END) {
       if (BEGIN->second == DFK) {
15         helpNr1 = BEGIN->first;
         KnotenNr1 = S1[helpNr1].first.getKnotenNummer();
         if (KnotenNr1 != KnotenNrD2) {
             LineNr1 = S1[helpNr1].first.getLineNr();
20             sprintf(NodeText,"Op%d",KnotenNr1);
             //sprintf(Bemerkung,"Line %d",LineNr1);
             strcpy(Bemerkung,SL1->first.getCodeLine());
             uwgknotenC hknoten1(CAUSE, KnotenNr1, NodeText,Bemerkung);
             pos1 = insert(hknoten1);
             verbindeEcken(posLOOP_KF,pos1,0);
25         }
         SliceC::iterator NEXTNODE = defineIterator(S1,KnotenNr1);
         SliceC::Nachfolger::iterator BEGIN2 = NEXTNODE->second.begin();
         SliceC::Nachfolger::iterator END2 = NEXTNODE->second.end();
         while (BEGIN2 != END2) {
30             if (BEGIN2->second == DFK) {
                 helpNr2 = BEGIN2->first;
                 if (NEXTNODE->first.getKnotenNummer() != KnotenNrD2) {
                     buildIn_LoopKF_ORPart(S1, posLOOP_KF,
35                     NEXTNODE, KnotenNrD2);
                 }
                 BEGIN2++;
             }
         }
40         BEGIN++;
     }
}

void uwggraphC::addAlldNodes(SliceC & S1, SliceC::iterator SLNODE, int posGatter,
45 int D2_RefNr) {
    int pos1 = 0;
    int ret = 0;
    int checkNr = 1;
    int helpNr1 = 0;
50    int helpNr2 = 0;
    int SliceNr2 = 0;
    int KnotenNr0 = 0;
    int KnotenNr1 = 0;
    int KnotenNr2 = 0;
55    int LineNr1 = 0;
    int LineNr0 = 0;
    char Bemerkung1[1000];
    char NodeText1[128];
    KnotenNr0 = SLNODE->first.getKnotenNummer();
60    LineNr0 = SLNODE->first.getLineNr();
    sprintf(NodeText1,"Op%d",KnotenNr0);
    //sprintf(Bemerkung1,"Line %d",LineNr0);
    strcpy(Bemerkung1,SLNODE->first.getCodeLine());
    uwgknotenC hknoten1(CAUSE,KnotenNr0,NodeText1,Bemerkung1);
65    pos1 = insert(hknoten1);
    verbindeEcken(posGatter,pos1,0);
    SliceC::Nachfolger::iterator BEGIN1 = SLNODE->second.begin();
    SliceC::Nachfolger::iterator END1 = SLNODE->second.end();
    while (BEGIN1 != END1) {
70        if (BEGIN1->second == DFK) {
            helpNr1 = BEGIN1->first;
            KnotenNr1 = S1[helpNr1].first.getKnotenNummer();
            SLNODE = defineIterator(S1,KnotenNr1);
            if ((KnotenNr1 != D2_RefNr) && (KnotenNr1 != KnotenNr0)) {
75                SliceC::Nachfolger::iterator BEGIN2 = S1[helpNr1].second.begin();

```



```

        insert(hknoten2,hknoten3,0);
        sprintf(NodeText,"Alt.1_D+(%d)",LineNr);
        uwgknotenC hknoten4(OR,NodeText);
        insert(hknoten2,hknoten4,0);
5         posIFDFOR = size() - 1;
        buildD2_A1_Part(S1, posIFDFOR, SLIF, SLORIG);
        }
        break;
10     case ELSE:
        {
            sprintf(NodeText,"Verzweigung_DF_Alt.2_D+(%d)",LineNr);
            uwgknotenC hknoten2(AND,NodeText);
            insert(hknoten1,hknoten2,0);
            sprintf(Bemerkung,"Alt.2_D+(%d)",LineNr);
15            sprintf(NodeText,"Alt.2_D+(%d)",LineNr);
            uwgknotenC hknoten3(CAUSE,NodeText,Bemerkung);
            insert(hknoten2,hknoten3,0);
            sprintf(NodeText,"Alt.2_D+(%d)",LineNr);
            uwgknotenC hknoten4(OR,NodeText);
20            insert(hknoten2,hknoten4,0);
            posIFDFORA2 = size() - 1;
            buildD2_A1_Part(S1, posIFDFORA2, SLIF, SLORIG);
            }
            break;
25     default:
            cout << "Ouch!!!" << endl;
        }
        return posIFDFOR;
30     }

void uwggraphC::buildD2_A1_Part(SliceC & S1, int posIFDFOR_D2, SliceC::iterator
SLIF, SliceC::iterator SLNODE) {
    int pos0_A1 = 0;
35    int pos1_A1 = 0;
    int helpNr0 = 0;
    int helpNr1 = 0;
    int KnotenNr0 = 0;
    int KnotenNr1 = 0;
40    int KnotenNr2 = 0;
    int LineNr0 = 0;
    int LineNr1 = 0;
    char NodeText0[128];
    char Bemerkung0[1000];
45    KnotenNr0 = SLNODE->first.getKnotenNummer();
    LineNr0 = SLNODE->first.getLineNr();
    sprintf(NodeText0,"Op%d",KnotenNr0);
    //sprintf(Bemerkung0,"Line %d",LineNr0);
    strcpy(Bemerkung0,SLNODE->first.getCodeLine());
50    uwgknotenC hknoten0(CAUSE,KnotenNr0,NodeText0,Bemerkung0);
    pos0_A1 = insert(hknoten0);
    verbindeEcken(posIFDFOR_D2,pos0_A1,0);
    SliceC::Nachfolger::iterator BEGIN0 = SLNODE->second.begin();
    SliceC::Nachfolger::iterator END0 = SLNODE->second.end();
55    while (BEGIN0 != END0) {
        helpNr0 = BEGIN0->first;
        KnotenNr1 = S1[helpNr0].first.getKnotenNummer();
        if (KnotenNr1 > KnotenNr0) {
            LineNr1 = S1[helpNr0].first.getLineNr();
60            sprintf(NodeText0,"Op%d",KnotenNr1);
            //sprintf(Bemerkung0,"Line %d",LineNr1);
            strcpy(Bemerkung0,S1[helpNr0].first.getCodeLine());
            uwgknotenC hknoten1(CAUSE,KnotenNr1,NodeText0,Bemerkung0);
            pos1_A1 = insert(hknoten1);
65            verbindeEcken(posIFDFOR_D2,pos1_A1,0);
            SliceC::Nachfolger::iterator BEGIN1 =
S1[helpNr0].second.begin();
            SliceC::Nachfolger::iterator END1 =
S1[helpNr0].second.end();
70            while (BEGIN1 != END1) {
                if (BEGIN1->second == DFK) {
                    helpNr1 = BEGIN1->first;
                    KnotenNr2 =
S1[helpNr1].first.getKnotenNummer();
75                    if (KnotenNr1 != KnotenNr2) {

```

```
defineIterator(S1,KnotenNr2);  
5  SLIF, SLNODE);  
    }  
    }  
    SliceC::iterator SLNODE =  
    buildD2_A1_Part(S1, posIFDFOR_D2,
```

T0E0E1 - 2840860


```

checkUWGNode(KnotenNr2);

5  == 0) {
    //HELPPUSE = findOutmostPUse(S1,HELPPUSE);
    (HELPPUSE->first.getKFGNodeType()) {
10      buildInLoopTree(S1, posKFOR_D2, HELPPUSE, SLNODE);
      dummy = 1;
15      break;
      IFC:
20      ret = buildInIfTree(S1, HELPPUSE, SLNODE, posKFOR_D2);
      dummy = 1;
      break;
25      cout << "Incorrect path in A1! " << endl;
      }
      else {
30        = S1[helpNr2].first.getLineNr();
        sprintf(NodeText0,"Op%d",KnotenNr2);
35        //sprintf(Bemerkung0,"Line %d",LineNr1);
        strcpy(Bemerkung0,S1[helpNr2].first.getCodeLine());
40        uwgknotenC hknoten1(CAUSE,KnotenNr2,NodeText0,Bemerkung0);
        = insert(hknoten1);
        verbindeEcken(posKFOR_D2,pos1_D2,0);
45        }
        BEGIN2++;
50      }
      BEGIN1++;
55    }
    BEGIN0++;
  }

60  SliceC::iterator uwggraphC::findOutmostPUse(SliceC & S1, SliceC::iterator SLPUSE) {
    int dummy = 0;
    int helpNr1 = 0;
    int checkNr = 0;
    int KnotenNr1 = 0;
65    SliceC::iterator RETURN = SLPUSE;
    SliceC::Nachfolger::iterator BEGIN1 = SLPUSE->second.begin();
    SliceC::Nachfolger::iterator END1 = SLPUSE->second.end();
    while ((BEGIN1 != END1) && (dummy != 1)){
      if (BEGIN1->second == KFK) {
70        helpNr1 = BEGIN1->first;
        KnotenNr1 = S1[helpNr1].first.getKnotenNummer();
        checkNr = checkUWGNode(KnotenNr1);
        if (checkNr == 0) {
          SLPUSE = defineIterator(S1,KnotenNr1);
75          RETURN = findOutmostPUse(S1, SLPUSE);
          dummy = 1;

```



```

        return RETURN;
    }

5   int uwggraphC::checkUWGNode(int SliceNr) {
        int dummy = 0;
        uwggraphC::iterator ITER = begin();
        while (ITER != end()) {
            if ((*ITER).first.getCauseNr() == SliceNr) {
10              dummy = 1;
            }
            ITER++;
        }
        if (dummy == 1)
15          return 1;
        else
            return 0;
    }

20   SliceC::iterator uwggraphC::defineIterator(SliceC & S1, int SliceNr) {
        int dummy = 0;
        SliceC::iterator ITER = S1.begin();
        SliceC::iterator HELP = S1.begin();
25         while ((ITER != S1.end()) && (dummy != 1)) {
            if ((*ITER).first.getKnotenNummer() == SliceNr) {
                HELP = ITER;
                dummy = 1;
            }
            ITER++;
30         }
        return HELP;
    }

35   void uwggraphC::SliceAusgeben(SliceC & S1) {
        //int a;
        ofstream Ziel("Slice.slc");
40         ostream_iterator<KFGLListNodeC> POSIT(Ziel, " Knoten\n");
        ostream_iterator<KFGLListNodeC> POSIT2(Ziel, "      Nachfolger: ");
        ostream_iterator<GraphKanteC> KANTEIT(Ziel, "\n");
        Ziel << "SLICE:" << endl << endl;
        for (int i = 0; i < S1.size(); ++i) {
45             Ziel << S1[i].first << " <";
            SliceC::Nachfolger::iterator IT = S1[i].second.begin();
            SliceC::Nachfolger::iterator ITEND = S1[i].second.end();
            while (IT != ITEND) {
                Ziel << S1[(*IT).first].first << ' ' // Ecke
50             << endl << "Kante:" << (*IT).second << ' '; // Kantenwert
                ++IT;
            }
            Ziel << ">\n";
        }
55     }

#include "uwgkante.h"
#include <iostream>

60     ostream& operator << ( ostream& os, const uwgkanteC& Node){
        os << Node.Number << endl ;
        return os;
    }

65

```

T.00001.1.0000000000

```

#include "uwgknoten.h"
#include <iostream>

ostream& operator << ( ostream& os, const uwgknotenC& Node){
5 //os << Node.GatterIdent << " " << Node.CauseNr << " " <<
Node.gattertext << endl ;
//return os;
if (Node.getNodeIdent() == EFFECT) {
    os << "%%EFFECT:\\" << Node.gatterbemerkung << "\":" <<
10 Node.gattertext << "\"," << Node.GatterIdent << ",,0;" << endl;
    return os;
}
else if (Node.getNodeIdent() == OR) {
    os << "%%OR:1:\\" << Node.gattertext << "\":" << "none\"," <<
15 Node.GatterIdent << ",,0;" << endl;
    return os;
}
else if (Node.getNodeIdent() == AND) {
    os << "%%AND:\\" << Node.gattertext << "\":" << "none\"," <<
20 Node.GatterIdent << ",,0;" << endl;
    return os;
}
else if (Node.getNodeIdent() == NOT) {
    os << "%%NOT:\\" << Node.gattertext << "\":" << "none\"," <<
25 Node.GatterIdent << ",,0;" << endl;
    return os;
}
/*else if (Node.getNodeIdent() == CAUSE) {
    os << "%%CAUSE:\\" << Node.gattertext << "\":" << "none\"," <<
30 Node.GatterIdent << ",,0;" << endl;
    return os;
}*/
else if (Node.getNodeIdent() == CAUSE) {
    os << "%%CAUSE:\\" << Node.gatterbemerkung << "\":" <<
35 Node.gattertext << "\"," << Node.GatterIdent << ",,0;" << endl;
    return os;
}
else {
    os << Node.GatterIdent << " " << Node.CauseNr << " " <<
40 Node.gattertext << endl ;
    return os;
}
}

45 int uwgknotenC::DummyNr = 1;

```

F.00001.00000000

The following publications are cited in this document:

[1] N. Leveson, Safety Verification of ADA Programs using software fault trees, IEEE Software, pages 48 to 59, July 1991

5

[2] Weiser M., *Program Slicing*, in: IEEE Transaction on Software Engineering, Vol. 10, No. 4, July 1984, pp. 352-357

[3] Liggesmeyer P., Modultest und Modulverifikation [Module Test and Module Verification] - State of the Art, Mannheim, Vienna, Zurich: BI Wissenschaftsverlag 1990

[4] DIN 25424-1: Fehlerbaumanalysen; Methoden und Bildzeichen [Fault Tree Analyses; Methods and Graphic Symbols], September 1981

15

[5] DIN 25424-2: Fehlerbaumanalyse; Handrechenverfahren zur Auswertung eines Fehlerbaums [Fault Tree Analysis; Manual Computation Methods for Evaluating a Fault Tree], Berlin, Beuth Verlag GmbH, April 1990

20

F.0021-0340660

ART 34 AMDT

Patent Claims

1. A method for ascertaining an overall fault description for
at least one section of a computer program, using a
5 computer,
- in which at least the section of the computer program is
stored,
 - in which a control flow description is ascertained for
10 the section of the computer program, which control flow
description describes a flow of control information in
the section of the computer program, and a data flow
description is ascertained for the section of the
computer program, which data flow description describes a
15 flow of data in the section of the computer program, and
said descriptions are combined into a joint flow
description for the section of the computer program,
 - in which program elements are selected from the section
of the computer program,
 - in which, for each selected program element, a stored
20 fault description associated with a respective reference
element is used to ascertain an element fault description
which describes possible faults in the respective program
element,
 - in which a fault description for a reference element
25 describes possible faults in the respective reference
element, and
 - in which the element fault descriptions are used to
ascertain the overall fault description, with a structure
of the overall fault description taking into account a
30 structure of the joint flow description.
2. The method as claimed in claim 1,
in which the control flow description is in the form of a
control flow graph.
- 35
3. The method as claimed in claim 1 or 2,
in which the data flow description is in the form of a data

1999P01974WO
PCT/DE00/01001

- 84a -

ART 34 AMDT

flow graph.

4. The method as claimed in one of the preceding claims,
- in which the fault description is in the form of a stored fault tree,
 - in which the element fault description is ascertained as an element fault tree, and
 - in which the overall fault description is ascertained as an overall fault tree.
- 5.
5. The method as claimed in one of the preceding claims,
- 10 used for fault analysis in the section of the computer program.
6. The method as claimed in one of the preceding claims,
- in which the overall fault description is ascertained as an overall fault tree,
 - in which the overall fault tree is altered in terms of prescribable boundary conditions.
- 15.
7. The method as claimed in claim 6,
- 20 in which the alteration is made by adding a complementary fault tree.
8. An arrangement for ascertaining an overall fault description for at least one section of a computer program, using a computer,
- 25 having a processor which is set up such that the following steps can be carried out:
- at least the section of the computer program is stored,
 - a control flow description is ascertained for the section of the computer program, which control flow description describes a flow of control information in the section of the computer program, and a data flow description is ascertained for the section of the computer program, which data flow description describes a flow of data in the section of the computer program, and said descriptions are combined into a joint flow description for the section of the computer program,
- 30
- 35

- 5
- program elements are selected from the section of the computer program,
 - for each selected program element, a stored fault description associated with a respective reference element
 - 5 is used to ascertain an element fault description which describes possible faults in the respective program element,
 - a fault description for a reference element describes possible faults in the respective reference element, and
 - 10 • the element fault descriptions are used to ascertain the overall fault description, with a structure of the overall fault description taking into account a structure of the joint flow description.
- 15 9. The arrangement as claimed in claim 8,
in which the processor is set up such that the control flow description is in the form of a control flow graph.
- 20 10. The arrangement as claimed in claim 8 or 9,
in which the processor is set up such that the data flow description is in the form of a data flow graph.
- 25 11. The arrangement as claimed in one of claims 8 to 10,
in which the processor is set up such that
- the fault description is in the form of a stored fault tree,
 - the element fault description is ascertained as an element fault tree, and
 - the overall fault description is ascertained as an
 - 30 overall fault tree.
- 35 12. The arrangement as claimed in one of claims 8 to 11,
used for fault analysis in the section of the computer program.
13. The arrangement as claimed in one of claims 8 to 12,

in which the processor is set up so that

- the overall fault description is ascertained as an overall fault tree,
- the overall fault tree is altered in terms of prescribable boundary conditions.

14. The arrangement as claimed in claim 13,
in which the processor is set up such that the alteration is made by adding a complementary fault tree.

15. A computer program product comprising a computer-readable storage medium on which a program is stored which, when it has been loaded into a memory in a computer, allows the computer to carry out the following steps for ascertaining an overall fault description for at least one section of a computer program:

- at least the section of the computer program is stored,
- a control flow description is ascertained for the section of the computer program, which control flow description describes a flow of control information in the section of the computer program, and a data flow description is ascertained for the section of the computer program, which data flow description describes a flow of data in the section of the computer program, and said descriptions are combined into a joint flow description for the section of the computer program,
- program elements are selected from the section of the computer program,
- for each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element,
- a fault description for a reference element describes possible faults in the respective reference element, and

- the element fault descriptions are used to ascertain the overall fault description, with a structure of the overall fault description taking into account a structure of the joint flow description.

5

16. A computer-readable storage medium on which a program is stored which, when it has been loaded into a memory in a computer, allows the computer to carry out the following steps for ascertaining an overall fault description for at least one section of a computer program:

10

- at least the section of the computer program is stored,
- a control flow description is ascertained for the section of the computer program, which control flow description describes a flow of control information in the section of the computer program, and a data flow description is ascertained for the section of the computer program, which data flow description describes a flow of data in the section of the computer program, and said descriptions are combined into a joint flow description for the section of the computer program,

15

20

- program elements are selected from the section of the computer program,
- for each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element,

25

- a fault description for a reference element describes possible faults in the respective reference element, and

30

- the element fault descriptions are used to ascertain the overall fault description, with a structure of the overall fault description taking into account a structure of the joint flow description.

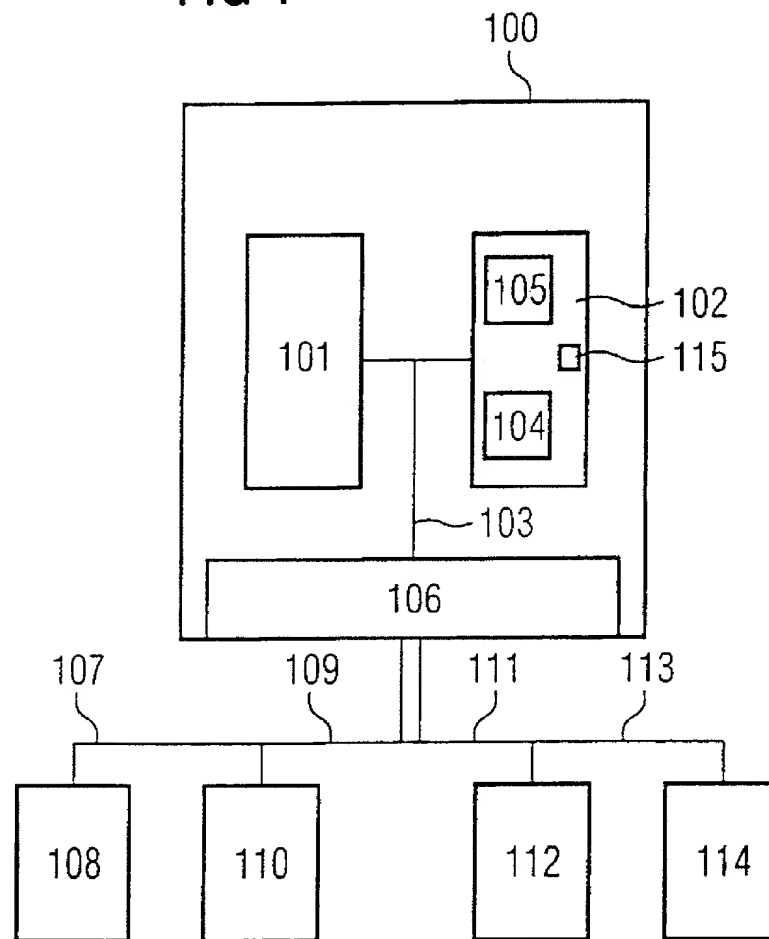
Method and arrangement for ascertaining an overall fault description for at least one section of a computer program, and computer program product and computer-readable storage medium

The section of the computer program is used to ascertain a control flow description and a data flow description, and program elements are selected from the section of the computer program. For each selected program element, a stored fault description associated with a respective reference element is used to ascertain an element fault description which describes possible faults in the respective program element. The element fault descriptions are used to ascertain the overall fault description, taking into account the control flow description and the data flow description.

Figure 2

1/12

FIG 1



2/12

FIG 2

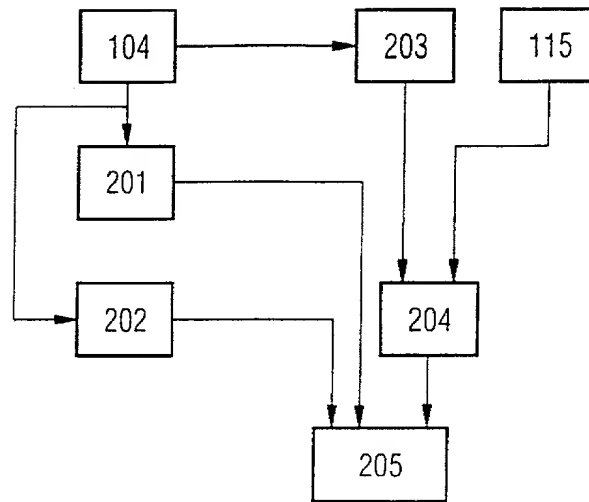


FIG 3

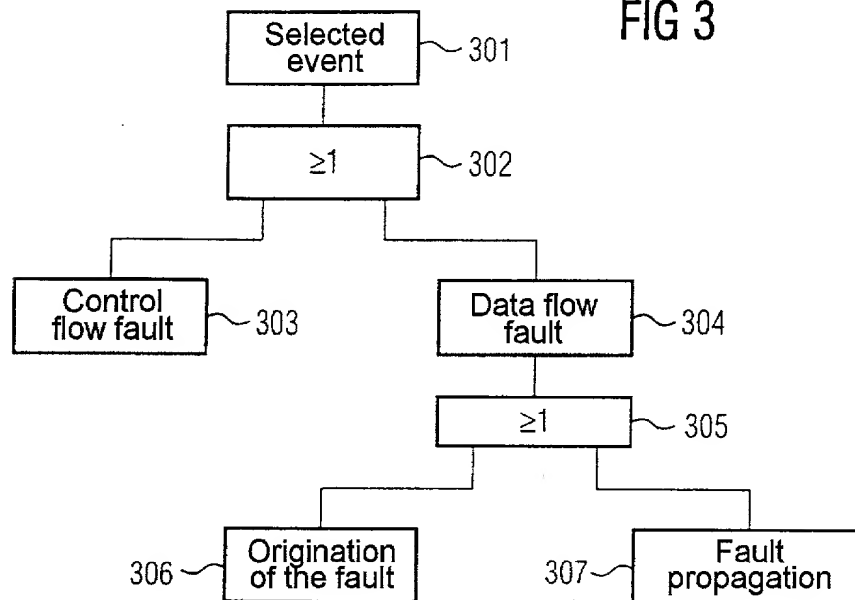


FIG 4A

401 ~ Control flow graph

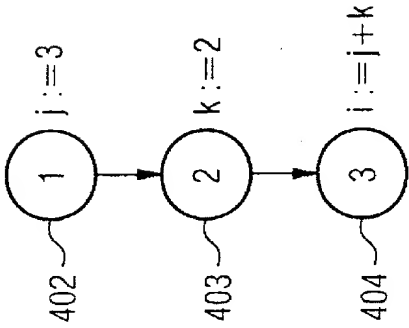


FIG 4B

410 ~ Slice

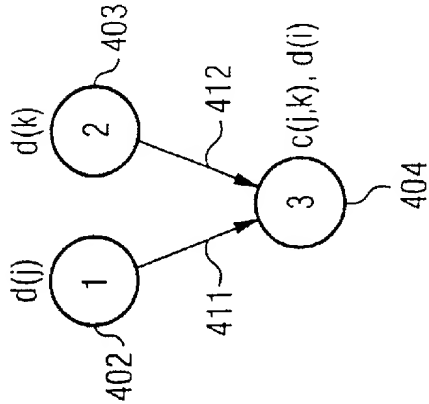
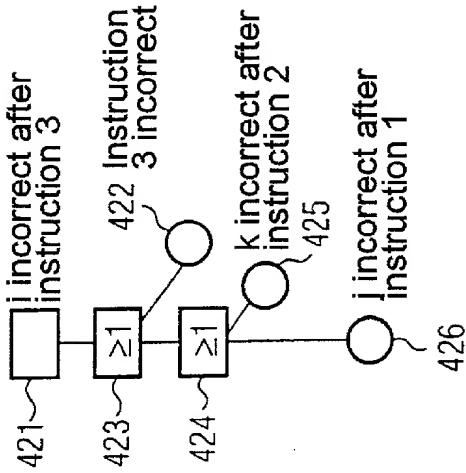


FIG 4C

420 ~ Fault tree



4/12

FIG 5A

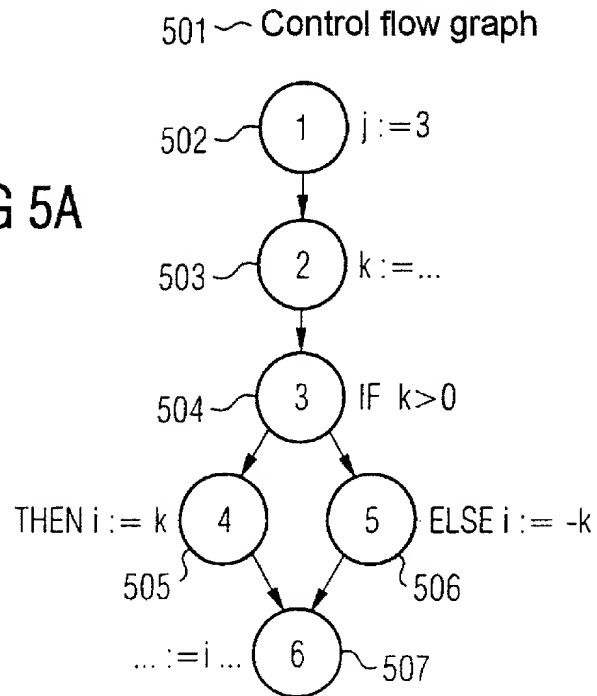
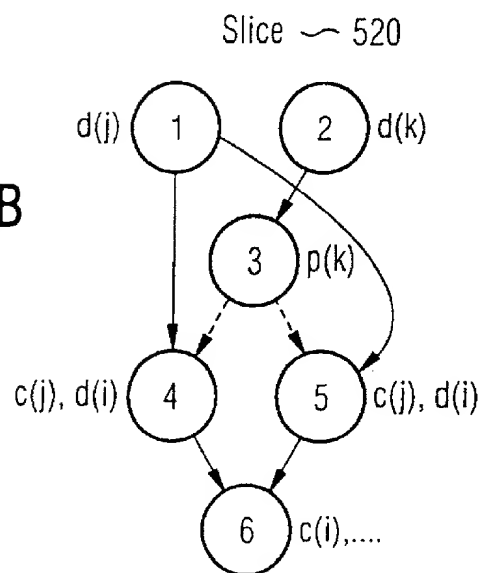


FIG 5B



6/12

FIG 6A

601 ~ Control flow graph

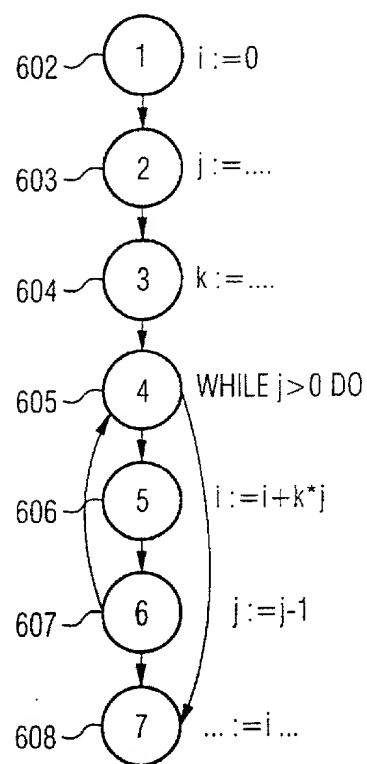
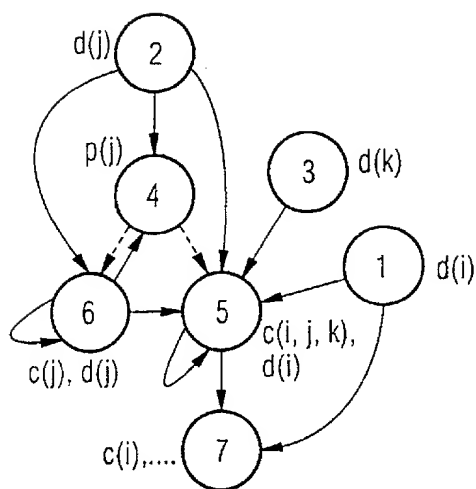


FIG 6B

Slice ~ 620



7/12

FIG 6C

640 ~ Fault tree

641 ~ \square i correct before instruction 7642 ~ ≥ 1

643

i correct after instruction 1

644 ~ $\&$

645

Loop body executed
at least twice

650

646 ~ \square Instruction 6 incorrect

651

Loop body executed at least once

652 ~ ≥ 1

Instruction 5 incorrect ~ 653

i incorrect after instruction 1 ~ 654

j incorrect after instruction 2 ~ 655

k incorrect after instruction 3 ~ 656

660 ~ ≥ 1

Loop decision 4 incorrect ~ 661

j incorrect after instruction 2 ~ 662

663 ~ $\&$

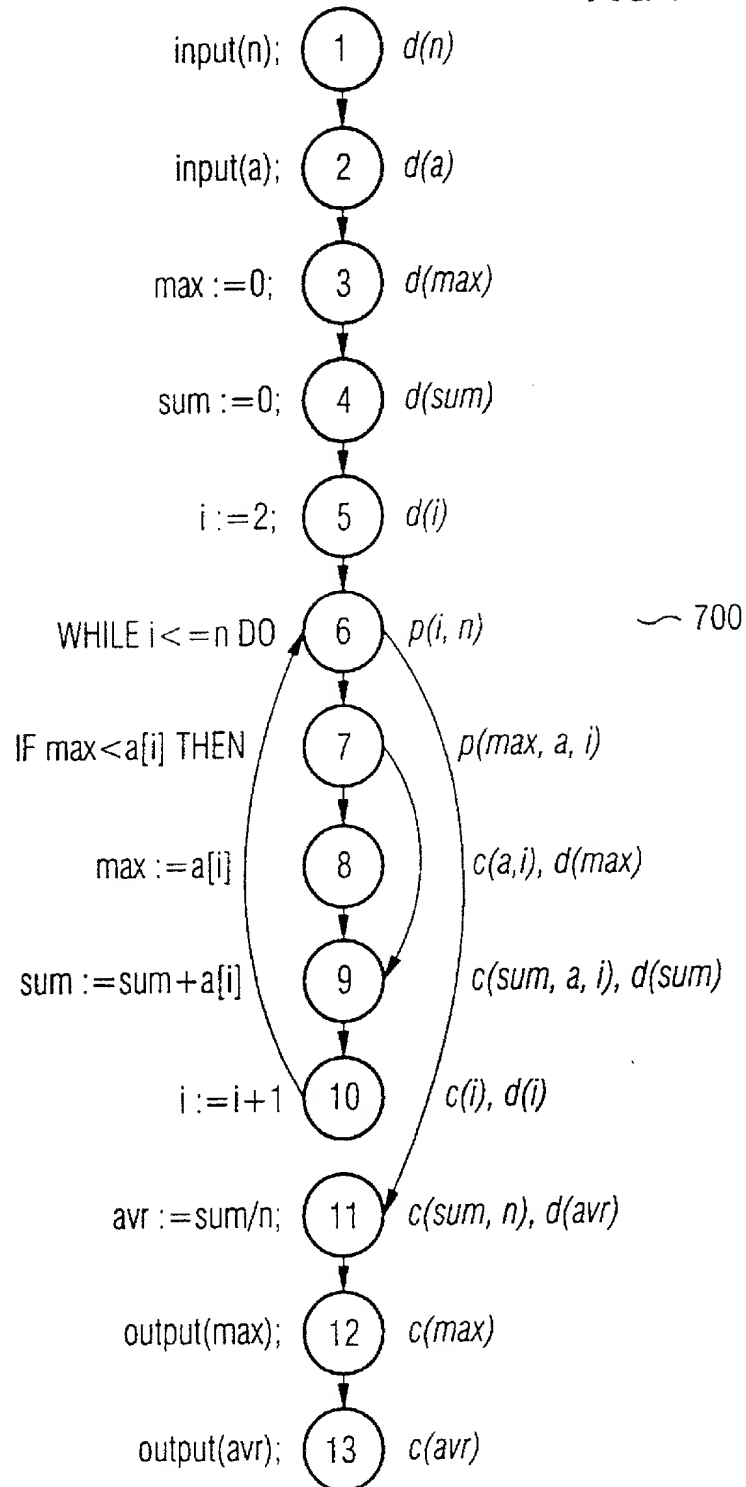
664

Instruction 6 incorrect

665 ~ \square Loop body executed at least once

8/12

FIG 7



9/12

FIG 8A

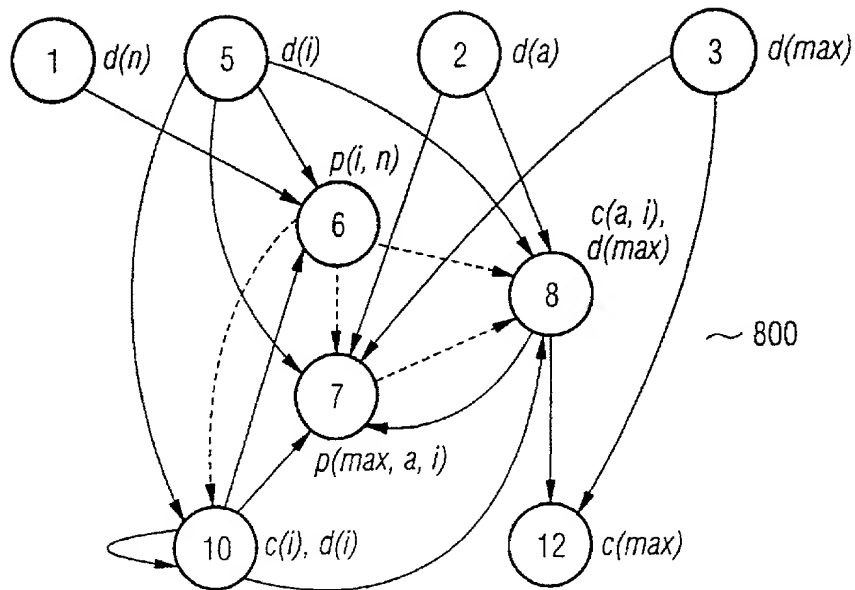
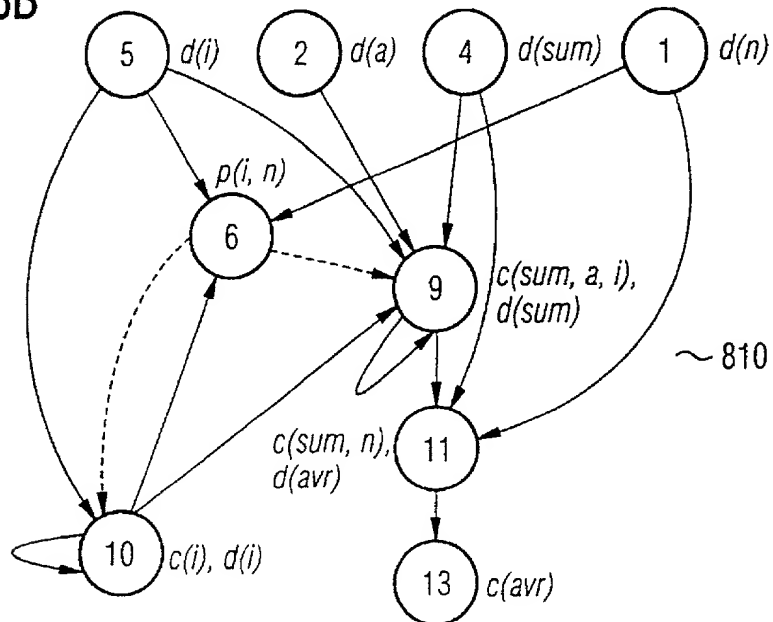
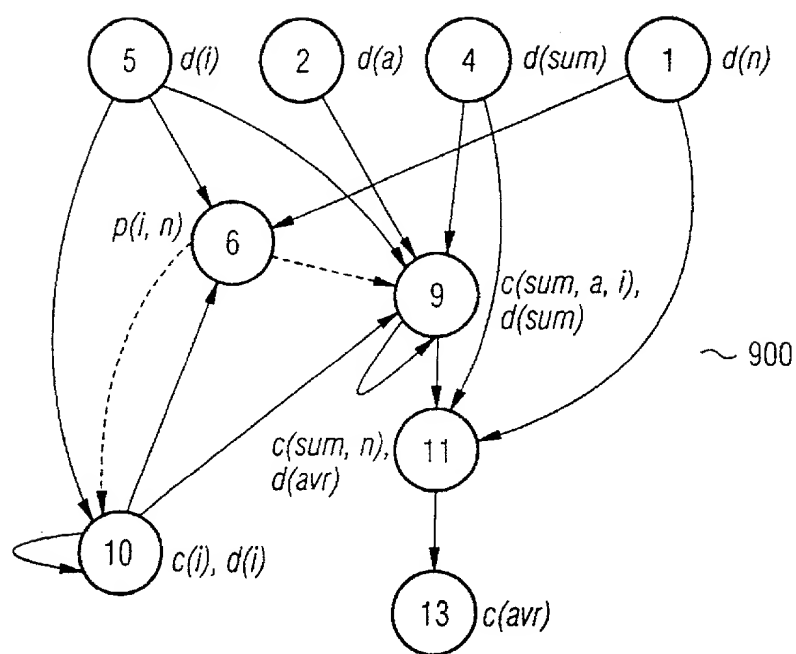


FIG 8B



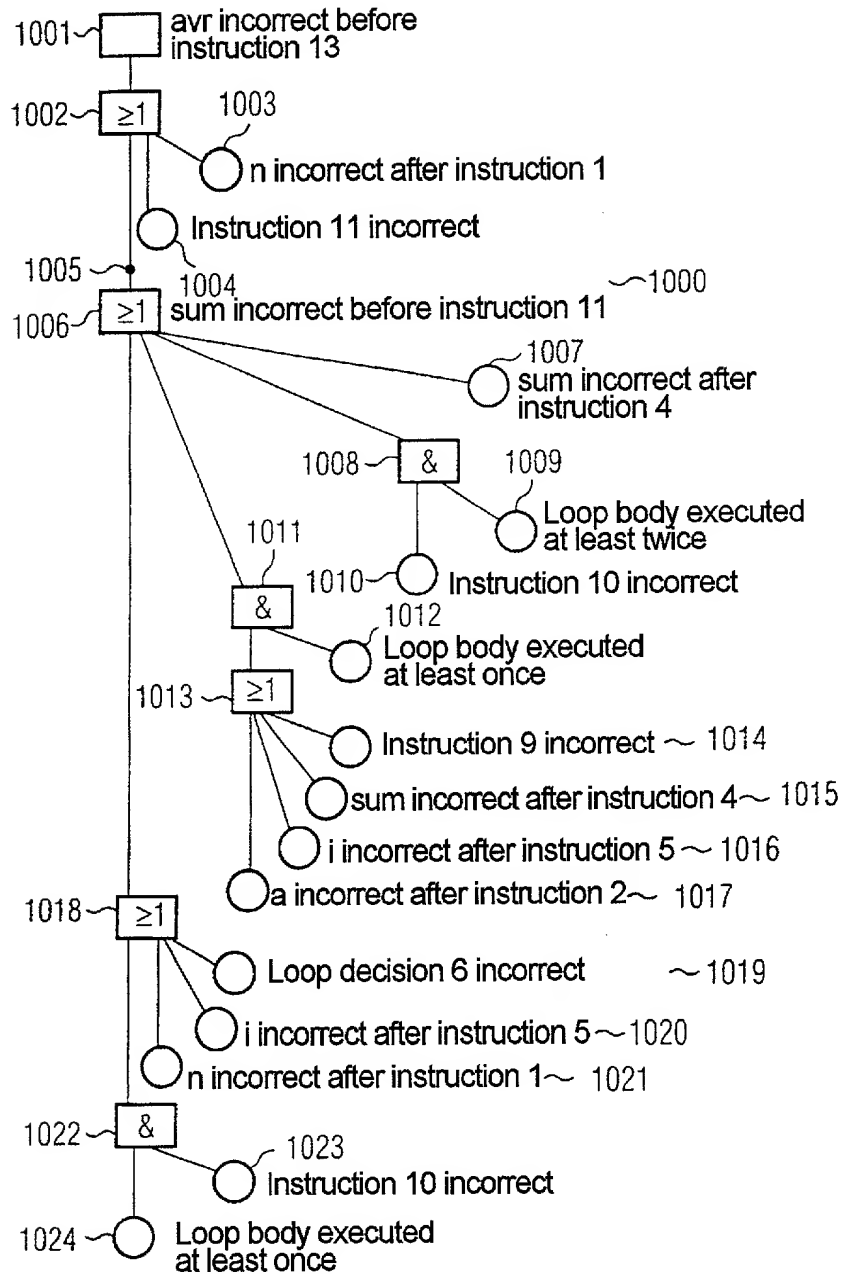
10/12

FIG 9



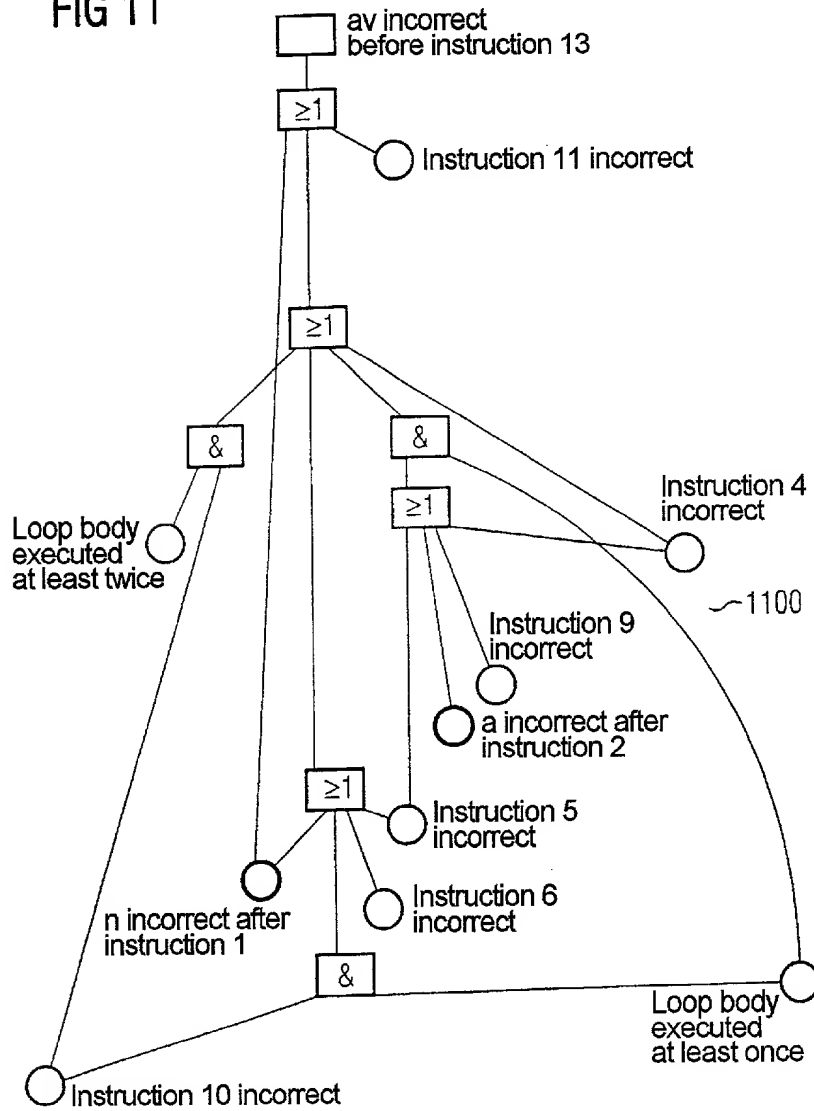
11/12

FIG 10



12/12

FIG 11



Declaration and Power of Attorney For Patent Application

Erklärung Für Patentanmeldungen Mit Vollmacht

German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden, nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Verfahren und Anordnung zur Ermittlung einer Gesamtfehlerbeschreibung zumindest eines Teils eines Computerprogramms sowie Computerprogramm-Erzeugnis und computerlesbares Speichermedium

Method and arrangement for determining a total error description of at least one part of a computer programme and computer programme product and computer-readable storage medium

deren Beschreibung

the specification of which

(zutreffendes ankreuzen)

☐ hier beigefügt ist.

☒ am 03.04.2000 als

PCT internationale Anmeldung

PCT Anmeldungsnummer PCT/DE00/01001

eingereicht wurde und am

abgeändert wurde (falls tatsächlich abgeändert).

(check one)

☐ is attached hereto.

☒ was filed on 03.04.2000 as

PCT international application

PCT Application No. PCT/DE00/01001

and was amended on

(if applicable)

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

German Language Declaration

Prior foreign applications
Priorität beansprucht

Priority Claimed

19925239.4

DE

02.06.1999

☒

☐

(Number)

(Country)

(Day Month Year Filed)

Yes

No

(Nummer)

(Land)

(Tag Monat Jahr eingereicht)

Ja

Nein

(Number)

(Country)

(Day Month Year Filed)

☐

☐

(Nummer)

(Land)

(Tag Monat Jahr eingereicht)

Yes

No

Ja

Nein

(Number)

(Country)

(Day Month Year Filed)

☐

☐

(Nummer)

(Land)

(Tag Monat Jahr eingereicht)

Yes

No

Ja

Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE00/01001

03.04.2000

anhängig

pending

(Application Serial No.)
(Anmeldeseriennummer)

(Filing Date D, M, Y)
(Anmeldedatum T, M, J)

(Status)
(patentiert, anhängig,
aufgegeben)

(Status)
(patented, pending,
abandoned)

(Application Serial No.)
(Anmeldeseriennummer)

(Filing Date D,M,Y)
(Anmeldedatum T, M, J)

(Status)
(patentiert, anhängig,
aufgeben)

(Status)
(patented, pending,
abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

German Language Declaration

VERTRETUNGSVOLLMACHT: Als benannter Erfinder beauftrage ich hiermit den nachstehend benannten Patentanwalt (oder die nachstehend benannten Patentanwälte) und/oder Patent-Agenten mit der Verfolgung der vorliegenden Patentanmeldung sowie mit der Abwicklung aller damit verbundenen Geschäfte vor dem Patent- und Warenzeichenamt: (Name und Registrationsnummer anführen)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

Customer No. 21171

And I hereby appoint

Telefongespräche bitte richten an:
(Name und Telefonnummer)

Direct Telephone Calls to: (name and telephone number)

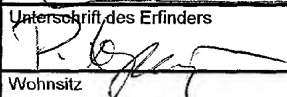
Ext. _____

Postanschrift:

Send Correspondence to:

Staas & Halsey LLP
700 Eleventh Street NW, Suite 500 20001 Washington, DC
Telephone: (001) 202 434 1500 and Facsimile (001) 202 434 1501

or
Customer No. 21171

Voller Name des einzigen oder ursprünglichen Erfinders:		Full name of sole or first inventor:	
Dr. PETER LIGGESMEYER		Dr. PETER LIGGESMEYER	
Unterschrift des Erfinders	Datum	Inventor's signature	Date
	8.11.2001		
Wohnsitz		Residence	
Potsdam, DEUTSCHLAND DE		Potsdam, GERMANY	
Staatsangehörigkeit		Citizenship	
DE		DE	
Postanschrift		Post Office Address	
Eichenring 27		Eichenring 27	
14469 Potsdam		14469 Potsdam	
Voller Name des zweiten Miterfinders (falls zutreffend):		Full name of second joint inventor, if any:	
Unterschrift des Erfinders		Second Inventor's signature	
Datum		Date	
Wohnsitz		Residence	
Staatsangehörigkeit		Citizenship	
Postanschrift		Post Office Address	

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).

AS_GraphKante.h

Entscheidungen

Decisions

Zaehlschleifenentscheidungen	count_loop_decisions
KnotenNummern	Node_Numbers
KnotenIdentifizierer	Node_Identifiers
ListeAusgeben	outputList
zaehleDeklarationen	countDeclarations
basisgroessenInDatei	basicvariablesInFile
KFGListeAusgeben	outputCFGList
KFGListeT	CFGListT
KnotenIdentT	NodeIDT
Nr	No
KnotenIdent	NodeID
KnotenNummer	NodeNumber
KFGListeC	CFGListC
uwgknoten.h	uwgnode.h
uwgkante.h	uwgedge.h
sliceAusgeben	outputSlice
posGatter	posGate
uwgkanteC	uwgedgeC
uwgknotnC	uwgnodeC
maxKnotentextLength	maxNodetextLength
maxBemerkLength	maxCommentLength
maxWahrVarLength	maxTrueVarLength
ftgatter	ftgate
gattertext	gatetext
gatterbemerkung	gatecomment
eingefügterKnotenFla	insertedNodeFla
EingefügterKnoten	InsertedNode
KnotenNummerEnde	NodeNumberEnd
SetKFGKnotenNummer	SetCFGNodeNumber
Zahl	Number
Zaehler	Counter
Verzweigung	Branch
Bemerkung	Comment
Gatterbemerkung	Gate comment